

PCTWORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 :

A61K 38/18**A1**

(11) International Publication Number:

WO 96/26737

(43) International Publication Date:

6 September 1996 (06.09.96)(21) International Application Number: **PCT/US96/02169**(22) International Filing Date: **14 February 1996 (14.02.96)**(30) Priority Data:
08/396,930 **1 March 1995 (01.03.95)** **US**(71) Applicant: **CREATIVE BIOMOLECULES, INC. [US/US]; 45 South Street, Hopkinton, MA 01748 (US).**(72) Inventors: **CHARETTE, Marc, F.; 18 Ellicott Street, Needham, MA 02192 (US). RUTHERFORD, Robert, Bruce; 15 Candlewood Lane, Farmington, CT 02032 (US).**(74) Agent: **FENTON, Gillian, M.; Testa, Hurwitz & Thibault, High Street Tower, 125 High Street, Boston, MA 02110 (US).**(81) Designated States: **AU, CA, JP, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).****Published***With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.*(54) Title: **MORPHOGEN-INDUCED DENTINE REGENERATION**

(57) Abstract

Disclosed are methods and compositions for inducing dentine morphogenesis in a mammal. The compositions include a morphogen and are useful, e.g., in methods for sealing a cavity and desensitizing a tooth to perception of pressure and/or temperature. Preferred morphogens for use herein include osteogenic proteins, e.g., OP-1.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AM	Armenia	GB	United Kingdom	MW	Malawi
AT	Austria	GE	Georgia	MX	Mexico
AU	Australia	GN	Guinea	NE	Niger
BB	Barbados	GR	Greece	NL	Netherlands
BE	Belgium	HU	Hungary	NO	Norway
BF	Burkina Faso	IE	Ireland	NZ	New Zealand
BG	Bulgaria	IT	Italy	PL	Poland
BJ	Benin	JP	Japan	PT	Portugal
BR	Brazil	KE	Kenya	RO	Romania
BY	Belarus	KG	Kyrgyzstan	RU	Russian Federation
CA	Canada	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic	KR	Republic of Korea	SE	Sweden
CG	Congo	KZ	Kazakhstan	SG	Singapore
CH	Switzerland	LI	Liechtenstein	SI	Slovenia
CI	Côte d'Ivoire	LK	Sri Lanka	SK	Slovakia
CM	Cameroon	LR	Liberia	SN	Senegal
CN	China	LT	Lithuania	SZ	Swaziland
CS	Czechoslovakia	LU	Luxembourg	TD	Chad
CZ	Czech Republic	LV	Latvia	TG	Togo
DE	Germany	MC	Monaco	TJ	Tajikistan
DK	Denmark	MD	Republic of Moldova	TT	Trinidad and Tobago
EE	Estonia	MG	Madagascar	UA	Ukraine
ES	Spain	ML	Mali	UG	Uganda
FI	Finland	MN	Mongolia	US	United States of America
FR	France	MR	Mauritania	UZ	Uzbekistan
GA	Gabon			VN	Viet Nam

Morphogen-Induced Dentine Regeneration

Field of the Invention

The present invention relates generally to the dental and biomedical arts. In certain embodiments, the invention more particularly relates to methods and compositions for stimulating mammalian odontoblasts and inducing morphogenesis of mammalian dentine.

Background of the Invention

- 5 In mammals, periodontal disease, such as gingivitis, can arise from the weakening of periodontal tissue by infectious agents (e.g., buccal microorganisms), nutritional deficiency (e.g. scurvy), or neoplastic disease (e.g., leukemia and lymphoma). Periodontal diseases often are characterized by inflammation, bleeding, tissue recession and/or ulceration. If not properly treated, periodontal diseases can contribute to tooth loss. For example, gingival lesions can arise
10 where bacterial plaque adheres to the tooth/gingiva interface and provokes local inflammation and/or recession of the gingiva. In the early stages, gingivitis associated with tooth sensitivity to perception of pressure and/or temperature. For example, afflicted teeth may ache upon contact with cold or hot stimuli. If untreated, this progresses to severe continual throbbing pain, ultimately associated with infection of the tooth pulp tissue, periodontal ligament, or alveolar
15 bone of the tooth socket. More severe complications, e.g., endocarditis, can arise where untreated lesions provide buccal microorganisms with a portal of entry into the afflicted individual's bloodstream. Harrison's Principles of Internal Medicine, 12th edition, 1991 (Wilson et al., eds.), pp. 242-243. Current treatments include professional cleaning to remove plaque and tartar, use of oral antiseptics, local and/or systemic antibiotic therapies, and/or surgical procedures
20 to remove periodontal pockets formed from periodontal tissue lesions and necrosis. Gingivitis thus is treated by debridement of lesioned gingiva and the affected tooth or tooth root surface adjoining the lesion site. Treated gingival lesions heal through the formation of scar tissue at the lesion site. Where tooth loss is imminent or has already occurred as a result of periodontal disease, a prosthetic tooth or removable bridge is substituted for the natural tooth.
- 25 Dental caries also is generally attributable to the weakening of tooth tissue by infectious agents or nutritional causes. A cavity, or carious lesion, often involves colonization and degradation of mineralized tooth tissue (e.g., enamel or dentine) by buccal microorganisms. If

- 2 -

untreated, the lesion site expands and can weaken, permeating the mineralized tooth wall and placing the tooth pulp tissue at risk of infection. Thus, an untreated carious lesion site also can provide buccal microorganisms with a portal of entry into the bloodstream. Conventional treatments for dental caries include ablation of lesioned dentine to expose a fresh surface of unaffected residual dentine, followed by sealing and restoration with an inert material suitable for dental use, e.g., silver amalgam, composite plastic, gold or porcelain. If infection has spread to the pulp tissue, it becomes necessary to extract the tooth or remove the contents of the pulp chamber and root canals prior to sealing and reconstruction with inert materials. Both approaches require the construction of permanent dental prostheses, such as bridges or crowns, which can become brittle over time.

Needs remain for improved treatment of dental caries and periodontal disease, including gingivitis. Particular needs remain for improved treatment methods and compositions which mitigate loss of teeth and associated tissue, including dentine, gingiva and pulp tissue. Still more particular needs remain for improved methods and compositions which allow for the regenerative healing of functional dental tissues following resection of carious or periodontal lesions, including dentine tissue, pulp, cementum, periodontal ligament, gingiva and the like.

Summary of the Invention

It is an object of this invention to provide means for inhibiting loss of dental tissue in mammals, as well as means for inducing regeneration thereof. It is an object of the present invention to provide means for stimulating proliferation and differentiation of odontoblasts in mammals, particularly primates. It also is an object of the present invention to provide means for stimulating expression of the odontoblast phenotype, including production of mineralized dentine matrix, by mammalian tooth pulp tissue, including primate tooth pulp tissue such as human tooth pulp tissue. Another object is to provide means for inhibiting the periodontal tissue damage and tooth loss associated with periodontal and other gum diseases, including gingivitis. Additional objects include providing means for desensitizing teeth to perception of pressure or temperature, as well as for sealing a tooth cavity by inducing formation of reparative dentine tissue. These and other objects, along with advantages and features of the invention disclosed herein, will be apparent from the description, drawings and claims that follow.

- 3 -

The invention provides methods and compositions for inhibiting periodontal and tooth tissue (collectively, dental tissue) loss in a mammal, particularly a human, including regenerating damaged tissue and/or inhibiting additional damage thereto. The methods and compositions of this invention can be used to prevent and/or inhibit tooth loss associated with gingivitis and other periodontal diseases. The present methods and compositions also can be used to desensitize teeth to perception of pressure and/or temperature, and pain associated, therewith in dental caries and gingivitis. The invention further provides methods and compositions for stimulating morphogenesis of mammalian dentine, including stimulating proliferation and differentiation of odontoblasts. In particular, the invention provides methods and compositions for stimulating expression of the odontoblast phenotype, including production of dentine matrix, by tooth pulp tissue in mammals, including primates. The present invention can be used to seal a cavity in a mammalian tooth by inducing the formation of reparative dentine. Thus, the invention reduces the need for tooth extraction or root canal therapy as treatments for dental caries or other dental damage in which pulp tissue is placed at risk.

The methods and compositions of this invention capitalize on the discovery that certain proteins of eukaryotic origin, defined herein as morphogens, induce morphogenesis of functional cells, tissues and organs in higher eukaryotes, particularly mammals, including humans. That is, morphogens induce or reinduce the fully integrated developmental cascade of cellular and molecular morphogenetic events that culminate in the formation of fully differentiated, functional tissue of a type appropriate to the context or local environment in which morphogenesis is induced, including any vascularization, connective tissue formation, innervation and the like characteristic of the naturally-occurring tissue. Morphogenesis therefore differs significantly from simple reparative healing processes in which scar tissue (e.g., fibrous connective tissue) is formed and fills a lesion or other defect in differentiated, functional tissue. Further, morphogenesis occurs in a "permissive environment" by which is meant a local environment that does not stifle or suppress morphogenesis (e.g., regeneration or regenerative healing). Permissive environments exist, e.g., in embryonic tissue or in wounded or diseased tissue, including tissue subjected to surgical intervention. Often, a permissive environment comprises a suitable matrix or substratum to which cells undergoing differentiation can anchor. Other components of a permissive

- 4 -

environment typically include signals, e.g., cell surface markers or extracellular matrix components, that direct the tissue specificity of differentiation.

Generally, morphogens are dimeric proteins that induce morphogenesis of one or more eukaryotic (e.g., mammalian) cells, tissues or organs. Of particular interest herein are morphogens that induce morphogenesis at least of mammalian dentine, including formation of reparative dentine at or apposite to a dental or periodontal lesion site in a mammalian tooth. Morphogens comprise a pair of polypeptides that, when folded, adopt a configuration sufficient for the resulting dimeric protein to elicit morphogenetic responses in cells and tissues displaying receptors specific for said morphogen. That is, morphogens generally induce all of the following biological functions in a morphogenically permissive environment: stimulating proliferation of progenitor cells; stimulating the differentiation of progenitor cells; stimulating the proliferation of differentiated cells; and supporting the growth and maintenance of differentiated cells. "Progenitor" cells are uncommitted cells that are competent to differentiate into one or more specific types of differentiated cells, depending on their genomic repertoire and the tissue specificity of the permissive environment in which morphogenesis is induced. Morphogens further can delay or mitigate the onset of senescence- or quiescence-associated loss of phenotype and/or tissue function. Morphogens still further can stimulate phenotypic expression of differentiated cells, including expression of metabolic and/or functional, e.g., secretory, properties thereof. In addition, morphogens can induce redifferentiation of committed cells under appropriate environmental conditions. As noted above, morphogens that induce proliferation and differentiation at least of mammalian odontoblasts, and/or support the growth, maintenance and functional properties of mammalian odontoblasts, including the formation of dentine matrix, are of particular interest herein. For purposes of the present invention, an "odontoblast" is any differentiated cell occurring or arising in mammalian tooth pulp tissue, that is competent to produce dentine matrix.

In preferred embodiments, the pair of morphogen polypeptides have amino acid sequences each comprising a sequence that shares a defined relationship with an amino acid sequence of a reference morphogen. Herein, preferred morphogen polypeptides share a defined relationship with a sequence present in morphogenically active human OP-1, Seq. ID No. 4. However, any one or more of the naturally occurring or biosynthetic sequences disclosed herein

- 5 -

similarly could be used as a reference sequence. Preferred morphogen polypeptides share a defined relationship with at least the C-terminal six cysteine domain of human OP-1, residues 43-139 of Seq. ID No. 4. Preferably, morphogen polypeptides share a defined relationship with at least the C-terminal seven cysteine domain of human OP-1, residues 38-139 of Seq. ID No. 4.

5 That is, preferred morphogen polypeptides in a dimeric protein with morphogenic activity each comprise a sequence that corresponds to a reference sequence or is functionally equivalent thereto.

Functionally equivalent sequences include functionally equivalent arrangements of cysteine residues disposed within the reference sequence, including amino acid insertions or deletions which alter the linear arrangement of these cysteines, but do not materially impair their relationship in the folded structure of the dimeric morphogen protein, including their ability to form such intra- or inter-chain disulfide bonds as may be necessary for morphogenic activity.

10 Functionally equivalent sequences further include those wherein one or more amino acid residues differs from the corresponding residue of a reference morphogen sequence, e.g., the C-terminal seven cysteine domain (also referred to herein as the conserved seven cysteine skeleton) of human OP-1, provided that this difference does not destroy morphogenic activity. Accordingly, conservative substitutions of corresponding amino acids in the reference sequence are preferred.

15 Amino acid residues that are "conservative substitutions" for corresponding residues in a reference sequence are those that are physically or functionally similar to the corresponding reference residues, e.g., that have similar size, shape, electric charge, chemical properties including the ability to form covalent or hydrogen bonds, or the like. Particularly preferred conservative substitutions are those fulfilling the criteria defined for an "accepted point mutation" in Dayhoff et al. (1978), 5 Atlas of Protein Sequence and Structure, Suppl. 3, ch. 22 (pp. 354-352), Natl. Biomed. Res. Found., Washington, D.C. 20007, the teachings of which are

20 incorporated by reference herein.

25

In certain embodiments, a polypeptide suspected of being functionally equivalent to a reference morphogen polypeptide is aligned therewith using the method of Needleman et al. (1970), 48 J.Mol. Biol. 443-453, implemented conveniently by computer programs such as the Align program (DNASTar, Inc). As noted above, internal gaps and amino acid insertions in the

30 candidate sequence are ignored for purposes of calculating the defined relationship,

- 6 -

conventionally expressed as a level of amino acid sequence homology or identity, between the candidate and reference sequences. "Amino acid sequence homology" is understood herein to mean amino acid sequence similarity. Homologous sequences share identical or similar amino acid residues, where similar residues are conservative substitutions for or "allowed point mutations" of corresponding amino acid residues in an aligned reference sequence. Thus, a candidate polypeptide sequence that shares 70% amino acid homology with a reference sequence is one in which any 70% of the aligned residues are either identical to or are conservative substitutions of the corresponding residues in a reference sequence.

Of particular interest herein are morphogens, which, when provided to the tooth and/or jawbone surfaces in a mammalian tooth socket, induce periodontal tissue formation where periodontal tissue has been lost or damaged. Of still more particular interest herein are morphogens which, when applied to a tooth surface, such as a dentinal surface, induce morphogenesis of new or reparative dentine. Such morphogens can be used to seal a tooth cavity or to desensitize a tooth to perception of pressure and/or temperature.

The present invention alternatively can be practiced with methods and compositions comprising a morphogen stimulating agent in lieu of a morphogen. A "morphogen stimulating agent" is a compound that stimulates *in vivo* production, e.g., expression, of a therapeutically effective concentration of an endogenous morphogen in the body of the mammal sufficient to regenerate damaged dental tissue and/or to inhibit additional damage thereto. Such compounds are understood to include substances which, when administered to a mammal, act on cells of tissue(s) or organ(s) that normally are competent to produce and/or secrete a morphogen encoded within the genome of the mammal, and which cause the endogenous level of the morphogen in the mammal's body to be altered. Endogenous or administered morphogens can act as endocrine, paracrine or autocrine factors. That is, endogenous morphogens can be synthesized by the cells in which morphogenetic responses are induced, by neighboring cells, or by cells of a distant tissue, in which circumstances the secreted endogenous morphogen is transported to the site of morphogenesis e.g., by the individual's bloodstream. In preferred embodiments, the agent stimulates expression and/or secretion of an endogenous morphogen so as to increase amounts thereof in dental tissues, such as alveolar bone, periodontium, cementum, dentine or pulp tissue cells.

- 7 -

In certain preferred aspects of the present invention, the morphogens described herein can induce regeneration of damaged or lost dentine tissue in a mammalian tooth. The morphogen can be provided topically or otherwise administered to the tooth tissue. For example, the morphogen can be dispersed in a biocompatible, porous carrier material that then is provided topically to the damaged dentine tissue. A useful carrier can be formulated from suitable organ specific tissue, e.g., bone or dentine, by demineralizing and guanidine-extracting the tissue to create an acellular matrix as described in U.S.S.Nos. 07/971,091, 08/153,343 and 08/174,605 the teachings of which are incorporated by reference herein. Synthetic materials also can be used. In some embodiments, the existing tooth tissue provides a suitable matrix. If a formulated matrix carrier is used, it should be a biocompatible, suitably modified acellular matrix having dimensions such that it allows the differentiation and proliferation of migratory progenitor cells, and contributes to a morphogenically permissive environment. Preferably, the matrix allows cellular attachment and is biodegradable or bioresorbable. Where the tissue locus to which the morphogen and matrix are applied lacks sufficient endogenous signals to direct the tissue specificity of morphogenesis, the matrix preferably further comprises tissue-specific components or is derived from tissue of the desired type. Matrices can be generated from dehydrated organ-specific tissue by, e.g., treating the tissue with solvents to substantially remove the cellular, non-structural components therefrom. Alternatively, the matrix can be prepared from a biocompatible, *in vivo* biodegradable structural molecule, optionally formulated with suitable tissue-specific cell attachment factors. Thus, collagen, laminin, hyaluronic and/or the like, can be used, as can synthetic polymers or copolymers of polylactic acid, polybutyric acid, polyglycolic acid and the like. Currently preferred structural molecules include tissue-specific collagens. Currently preferred cell attachment factors include glycosaminoglycans and proteoglycans. Preferably collagens, glycosaminoglycans and/or proteoglycans are used that are of the same types as those that are naturally found in dental tissues. If needed, the matrix can be treated with an agent effective for enhancing porosity thereof, so as to create a scaffold structure suitable for cell influx and attachment.

Alternatively, the morphogen can be applied in association with a carrier that maintains the morphogen substantially at the site of application, and/or enhances the controlled delivery of morphogen substantially at the site at which morphogenesis is to be induced. Such carriers also

- 8 -

are disclosed in U.S.S.Nos. 07/971,091, 08/155,343 and 08/174,605. Useful carriers include compositions having a high viscosity, such as that provided by glycerol and the like, as well as carrier materials formulated from extracellular matrices and/or which contain laminin, collagen, and/or biocompatible synthetic polymers, such as polybutyric, polylactic, polyglycolic acids and copolymers thereof.

Accordingly, the present morphogens can be used to stimulate morphogenesis of new or reparative dentine in a mammalian tooth, including the formation of dentine matrix by mature, differentiated or newly formed odontoblasts, i.e., by competent cells of the tooth pulp tissue. That is, the present morphogens can stimulate proliferation, differentiation and/or phenotypic expression of mammalian cells competent to elaborate dentine matrix, including odontoblasts and/or pulp connective tissue cells. This morphogenetic activity is responsible for the formation of reparative dentine in mammalian teeth. Thus, the present morphogens can be used to increase thickness of a mammalian tooth wall; that is, to increase the thickness of mineralized tissue (dentine, enamel and/or cementum) separating viable tooth pulp tissue from the buccal environment. As a result, the present morphogens can be used to reduce the risk of tooth wall fracture, particularly at sites where the tooth wall is thin or weakened due to association with a gingival lesion site or a cavity.

Thus, the present invention can be used to seal a tooth cavity, up to and including a Stage V cavity, in a mammalian tooth, particularly a primate tooth such as a human tooth. Carious tissue preferably is ablated from the cavity site to expose a fresh surface of residual dentine therein, preferably transverse to luminae of dental canaliculi within the tooth. The residual dentine surface preferably is located up to about 1 mm, more preferably up to about 0.5 mm, still more preferably up to about 0.2 mm from the pulp chamber wall (i.e., from a mature odontoblast layer at the dentine/pulp interface). Application of a morphogen to this surface prior to or concurrently with tooth reconstruction, including filling of the site of the carious lesion with a suitable material, induces formation of reparative dentine matrix within the reconstructed tooth. In this manner, risk of fracture in the residual dentine, and subsequent treatment by root canal therapy or tooth extraction, can be avoided.

- 9 -

Similarly, the present invention can be used to desensitize mammalian teeth to perception of pressure and/or temperature in an individual afflicted with periodontal disease, e.g., gingivitis. Following debridement of surfaces within a gingival lesion, including removal of bacterial plaque or tartar, a morphogen is applied to an exposed dentinal surface therein,
5 preferably in an amount effective for stimulating formation of reparative dentine apposite said surface. Reparative dentine so formed can be within or external to the pulp chamber of the treated tooth, and serves as an enhanced protective barrier between the pulp tissue and the buccal environment. Further, morphogen applied to a healthy gingival surface adjoining the lesion site promotes gingival regeneration and/or retards gingival recession.

10 In the above-mentioned embodiments, morphogens or morphogen stimulating agents are applied, e.g., topically or by local injection, to a tooth surface e.g., a dentinal surface. Preferably, the surface is transverse to luminae of dental canaliculi within naturally formed tooth dentine, such that fluid microcontact can be established between applied morphogen and odontoblasts or pulp tissue present within the tooth. The morphogen can be applied solubilized
15 or otherwise dispersed (e.g., as a colloidal suspension or emulsion) in a physiologically compatible liquid vehicle, e.g., comprising physiological saline solution, or in a vehicle, e.g., comprising ethanol, that evaporates under physiological conditions to leave a morphogen residue adsorbed on the tooth surface. Alternatively, the morphogen can be sorbed on a matrix such as a biocompatible, acellular matrix suitable for sealing or filling defects in mammalian teeth, e.g., as
20 described above. Morphogen-sealed defects can, if desired, be filled or reconstructed to restore original tooth dimensions using conventional dental reconstruction materials.

In all such embodiments, the morphogen-treated dentinal surface should be rendered essentially free of buccal microorganisms, and aseptic conditions should be maintained in the treated locus during the time period in which morphogenetic activity is induced.

25 Morphogens and morphogen-stimulating agents of the present invention also can be provided to periodontium and/or tooth tissues together with other molecules ("cofactors") known to have a beneficial effect in treating damaged dental tissues, particularly cofactors capable of mitigating or alleviating symptoms typically associated with dental tissue damage and/or loss. Examples of such cofactors include antiseptics such as chlorhexidine and tetracycline, and fluoride, Examples of such cofactors include antiseptics such as chlorhexidine and tetracycline, and fluoride, Examples of such cofactors include antiseptics such as chlorhexidine and tetracycline, and fluoride,

- 10 -

antibiotics, including tetracycline, amin glycosides, macr lides, penicillins and cephalosporins, anaesthetics and analgesics, and other non-steroidal anti-inflammatory agents.

Brief Description of the Drawings

The foregoing and other objects, features and advantages of the present invention, as
5 well as the invention itself, will be more fully understood from the following description of preferred embodiments, when read together with the accompanying drawings, in which:

FIGURE 1 is a schematic illustration of a healthy mammalian tooth in a tooth socket.

FIGURE 2, panels 2-1 through 2-12, depicts alignment of sequences of various
naturally occurring morphogens with a preferred reference sequence of human OP-1, residues 38-
10 139 of Seq. ID No. 4. Morphogens shown in FIGURE 4 also are identified in Table I, above and in the Sequence Listing.

FIGURE 3 is a digitized video image of a typical tissue section through a primate tooth treated with morphogen, and shows morphogen-induced reparative dentine therein. Bar is 0.5 mm, original magnification 2.5x.

15 FIGURE 4 is a bar graph illustration of results establishing that morphogen stimulation of new or reparative dentine formation is dose dependent. In this figure, the dose applied of recombinant human OP-1 is shown in μg on the X-axis, and the surface area in mm of induced dentine is shown on the Y-axis.

FIGURE 5 is a line graph illustration of results establishing that morphogen stimulates
20 new or reparative dentine formation under thin bridges of residual natural dentine. In this figure, equivalent amounts (e.g., $10\mu\text{g}$) of recombinant human OP-1 were applied to residual dentine bridges of the thicknesses shown along the X-axis.

FIGURE 6 is a line graph illustration of results comparing the effects of recombinant human OP-1 to a conventional agent, $\text{Ca}(\text{OH})_2$, on stimulation of new or reparative dentine under
25 thin bridges of residual dentine. Here as well, equivalent amounts (e.g., $10\mu\text{g}$) of recombinant

- 11 -

human OP-1 or Ca(OH)_2 were applied as indicated to residual dentine bridges of the thicknesses shown on the X-axis.

Detailed Description of Preferred Embodiments

5 It has been discovered that the morphogens described herein can stimulate tissue formation, including morphogenesis or regeneration of lost or damaged mammalian dental tissue, including dentine. The invention can be used to desensitize teeth, retard gingival recession, seal cavities, increase thickness of the tooth wall, and reduce the risk of tooth wall fracture. The invention is practiced using a morphogen or morphogen-stimulating agent, as defined herein, according to the procedures described herein.

10 Provided below is a description of tooth anatomy and useful morphogens, including methods for their production and formulation, as well as exemplary, non-limiting examples which (1) demonstrate the suitability of the morphogens described herein in the methods of the invention, and (2) provide assays with which to test candidate morphogens for their efficacy.

I. Tooth Anatomy

15 A vertical section of a mammalian tooth in the tooth socket is shown schematically in FIGURE 1. The crown 6 of the tooth is composed of enamel 8 and dentine 22. The pulp chamber 12 is seen in the interior of the crown 6 and the center of the root 10; it extends downward into the bony area 14, 16, 18 and opens by a minute orifice, the apical foramen 20, at the extremity of the root 10. The pulp chamber 12 contains dental pulp, a loose connective tissue
20 richly supplied with blood vessels and nerves, entering the chamber through the apical foramen 20. Some of cells of the pulp tissue, i.e., odontoblasts, the precursors of dentine 22, are arranged generally as a layer on the wall of the pulp chamber 12. During development of the tooth, odontoblasts are columnar, but later, after the dentine 22 is fully formed, they become flattened and resemble osteoblasts.

25 The solid portion or mineralized wall of the mature tooth includes dentine 22, enamel 8, and a thin layer of cementum 24, which is disposed on the surface of the root 25. Enamel 8 is formed during development of the tooth from ameloblasts, and cementum 24 is formed from

- 12 -

cementoblasts. In a fully developed tooth, the principal mass of the tooth comprises dentine 22, which is made up of hydroxyapatite crystals embedded in a strong meshwork of collagen fibers. The dentine includes a number of minute wavy and branching tubes called dental canaliculi, embedded in a dense homogeneous substance, the matrix. The dental canaliculi are parallel with one another and open at their inner ends into the pulp chamber 12. The dentine matrix is translucent and comprises the majority of the inorganic mass of the dentine. It includes a number of fine fibrils, which are continuous with the fibrils of the dental pulp. After the inorganic matter has been removed by steeping a tooth in weak acid, the remaining organic matter may be torn into laminae that run parallel with the pulp chamber 12 across the direction of the tubes.

The cementum 24 is disposed as a thin mineralized layer covering the tooth root. It extends from where the enamel terminates to the apex of each root, where it is usually very thick. Cementum resembles bone in structure and chemical composition in that it contains, sparingly, the lacunae and canaliculi that characterize true bone; in the thicker portions of the cementum, the lamellae and Haversian canals peculiar to bone also are found. As a result of aging, the cementum increases in thickness and the pulp chamber also becomes partially filled with a hard substance that is intermediate in structure between dentine and bone (referred to herein as "osteodentine"). It appears to be formed by a slow conversion of the dental pulp, which shrinks or even disappears.

The periodontal ligament, or periodontal membrane 26, is the layer of periodontal tissue which forms a cushion between the cementum 24 and the bone 14, 16, 18; it holds the tooth in position by suspending it in the socket (alveolus) of the jawbone. The periodontal ligament is a highly organized tissue which is formed from periodontal fibroblasts. It organizes the collagen fibers which pass directly from the bone of the jaw into the cementum.

Thus, as used herein, "tooth" refers to a natural or synthetic composition essentially defining the shape of a natural mammalian tooth, having a solid tooth body, including a crown and tooth root. "Periodontium" defines the tissues which surround the tooth in the tooth socket and includes both periodontal ligament and cementum. "Gingiva" defines the dense fibrous tissue, covered by oral mucosa, that envelopes the alveolar bone (tooth socket) processes of the upper and lower jaws, as well as the mineralized tooth wall as it emerges from the periodontium. "Viable" tissue means living, substantially healthy tissue essentially free of micro organisms and

- 13 -

infection associated therewith. In particular, viable tissue means viable dental tissue such as enamel, dentine, tooth pulp, gingiva, cementum and periodontal ligament. "Enhancing viability" of dental tissue means improving the structural and functional integrity of living tissue, including improving the clinical status of damaged or diseased tissue. "Viable tooth" refers to an implanted
5 natural tooth with a living tooth root. "Inhibit loss" of dental tissue, as used herein, means inhibiting damage to, and/or loss of, dental tissue and includes regenerating lost, damaged or diseased tissue and/or inhibiting additional damage thereto.

"Residual dentine" means naturally formed, healthy dentine tissue, e.g., adjoining a carious or gingival lesion, particularly a lesion from which infected dentine has been ablated
10 and/or bacterial plaque or tartar has been debrided. Naturally formed dentine tissue comprises tubules, the dental canaliculi, extending generally radially through the dentine from the layer of odontoblasts lining the pulp chamber wall (described above in connection with FIGURE 1). Thus, a dentinal surface "transverse to the lumina of dental canaliculi" is a dentine surface disposed on any plane that intersects rather than parallels the lumina of one or more dental
15 canaliculi. A "dentinal" surface can define a natural boundary of naturally formed dentine, or a fresh surface of dentine exposed by drilling or other dental techniques, or by fracture or chipping of the tooth wall. A treatment or stimulation "apposite" to a dentinal surface means a treatment or stimulation in juxtaposition or close proximity to the dentinal surface (e.g., separated from said surface by up to about a 1mm thickness of intervening tissue such as residual dentine).
20 "Reparative dentine" comprises atubular dentine matrix elaborated by mature or proliferating odontoblasts or other competent cells of the pulp connective tissue, and can be formed within the pulp chamber of a mammalian tooth.

"Symptom alleviating cofactor" refers to one or more conventional pharmaceuticals which can, if desired, be included in compositions of this invention and which alleviate or mitigate
25 one or more of the symptoms typically associated with loss of or damage to dental tissue. Exemplary cofactors include antibiotics, antiseptics, non-steroidal antiinflammatory agents, anaesthetics and analgesics.

- 14 -

II. Useful Morphogens

Morphogens useful in this invention include eukaryotic proteins originally identified as osteogenic proteins (see U.S. Patent 5,011,691, incorporated herein by reference), such as the OP-1, OP-2, OP-3 and CBMP2 proteins (Seq. ID Nos. 4-9, 15-22, 25 and 26), as well as amino acid sequence-related proteins such as DPP (Seq. ID No. 10, from *Drosophila*), Vgl (Seq. ID No. 11, from *Xenopus*), Vgr-1 (Seq. ID No. 12, from mouse), GDF-1 (Seq. ID Nos. 13, 30 and 31, from humans, see Lee (1991), 88 PNAS 4250-4254), 60A (Seq. ID Nos. 23 and 24, from *Drosophila*, see Wharton et al. (1991), 88 PNAS 9214-9218), dorsalin-1 (from chick, see Basler et al. (1993), 73 Cell 687-702 and GenBank accession number L12032) and GDF-5 (from mouse, see Storm et al. (1994), 368 Nature 639-643). Additional useful morphogens include biosynthetic morphogen constructs disclosed in U.S. Pat. No. 5,011,691, e.g., COP-1, 3-5, 7 and 16. See also U.S. Pat. No. 4,968,590, incorporated herein by reference.

Naturally occurring proteins identified and/or appreciated herein to be morphogens form a distinct subgroup within the loose evolutionary grouping of sequence-related proteins known as the TGF β superfamily or supergene family. The naturally occurring morphogens share substantial amino acid sequence homology in their C-terminal regions (domains). Typically, the above-mentioned naturally occurring morphogens are translated as a precursor, having an N-terminal signal peptide sequence, typically less than about 30 residues, followed by a "pro" domain that is cleaved to yield the mature C-terminal domain. The signal peptide is cleaved rapidly upon translation, at a cleavage site that can be predicted in a given sequence using the method of Von Heijne (1986), 14 Nucleic Acids Research 4683-4691. The pro domain typically is about three times larger than the fully processed mature C-terminal domain. Herein, the "pr" form of a morphogen refers to a morphogen comprising a folded pair of polypeptides each comprising the pro and mature domains of a morphogen polypeptide. Typically, the pro form of a morphogen is more soluble than the mature form under physiological conditions. The pro form appears to be the primary form secreted from cultured mammalian cells.

Table I, below, summarizes various naturally occurring morphogens identified to date, including their nomenclature as used herein, their Seq. ID references, and publication sources for the amino acid sequences for the full length proteins not included in the Seq. Listing. Each of the

- 15 -

generic terms set forth in Table I is intended and should be understood to embrace morphogenically active proteins expressed from nucleic acids encoding the identified sequence mentioned below and set forth in the sequence listing, or a morphogenically active fragment or precursor thereof, including functional equivalents thereof such as naturally occurring and biosynthetic variants thereof. Naturally occurring variants thereof include allelic variant forms isolated from other individuals of a single biological species, and phylogenetic counterpart (species) variant forms isolated from phylogenetically distinct biological species. The disclosure of publications mentioned below is incorporated herein by reference.

TABLE I

10	"OP-1"	Refers generically to morphogenically active proteins expressed from nucleic acid encoding the human OP-1 protein disclosed in Seq. ID No. 4 ("hOP-1"), and includes at least mouse OP-1, Seq. ID No. 5 ("mOP-1"). In each of human and mouse OP-1, Seq. ID Nos. 4 and 5, the conserved seven cysteine skeleton is defined by residues 38 to 139. cDNA sequences and amino acid sequences encoded therein and corresponding to the full length proteins are provided in Seq. ID Nos. 15 and 16 (hOP1) and Seq. ID Nos. 17 and 18 (mOP1.) The mature proteins are defined by residues 293-431 (hOP1) and 292-430 (mOP1). The "pro" regions of the proteins, cleaved to yield the mature, morphogenically active proteins are defined essentially by residues 30-292 (hOP1) and residues 30-291 (mOP1).
15		
20		
	"OP-2"	Refers generically to morphogenically active proteins expressed from a nucleic acid encoding the human OP-2 protein disclosed in Seq. ID No. 6 ("hOP-2"), and includes at least mouse OP-2 ("mOP-2", Seq. ID No. 7). In each of human and mouse OP-2, the conserved seven cysteine skeleton is defined by residues 38 to 139 of Seq. ID Nos. 6 and 7. cDNA sequences and amino acid sequences encoded therein and corresponding to the full length proteins are provided in Seq. ID Nos. 19 and 20 (hOP2) and Seq. ID Nos. 21 and 22 (mOP2.) The mature proteins are defined essentially by residues 264-402 (hOP2) and 261-399 (mOP2). The "pro" regions of the proteins, cleaved to yield the mature, morphogenically active
25		

- 16 -

proteins are defined essentially by residues 18-263 (hOP2) and residues 18-260 (mOP1).

- 5 "OP-3" Refers generically to morphogenically active proteins expressed from a nucleic acid encoding the mouse OP-3 protein disclosed in Seq. ID No. 26 ("mOP-3"). The conserved seven cysteine domain is defined by residues 298 to 399 of Seq. ID No. 26, which shares greater than 79% amino acid identity with the corresponding mOP-2 and hOP-2 sequences, and greater than 66% identity with the corresponding OP-1 sequences. A cDNA sequence encoding the above-mentioned amino acid sequence is provided in Seq. ID No. 25. OP-3 is unique among the morphogens identified to date in that the residue at position 9 in the conserved seven cysteine domain (e.g., residue 315 of Seq. ID No. 26) is a serine, whereas other morphogens typically have a tryptophan at this location.
- 10 "CBMP2" Refers generically to morphogenically active proteins expressed from a nucleic acid encoding the CBMP2 proteins, including at least human CBMP2A ("CBMP2A(fx)", Seq ID No. 8) and human CBMP2B ("CBMP2B(fx)", Seq. ID No. 9). The amino acid sequence for the full length proteins, referred to in the literature as BMP2A and BMP2B, or BMP2 and BMP4, appear in Wozney, et al. (1988), 242 Science 1528-1534. The pro domain for BMP2 (BMP2A) likely includes residues 25-248; the mature protein, residues 249-396. The pro domain for BMP4 (BMP2B) likely includes residues 25-256; the mature protein, residues 257-408.
- 15 "DPP(fx)" refers to proteins encoded by the Drosophila DPP gene and defining the conserved seven cysteine skeleton (Seq. ID No. 10). The amino acid sequence for the full length protein appears in Padgett, et al (1987), 325 Nature 81-84. The pro domain likely extends from the signal peptide cleavage site to residue 456; the mature protein likely is defined by residues 457-588.
- 20 "Vgl(fx)" refers to proteins encoded by the Xenopus Vgl gene and defining the conserved seven cysteine skeleton (Seq. ID No. 11). The amino acid sequence for the full length protein appears in Weeks (1987), 51 Cell 861-867. The prodomain likely

- 17 -

extends from the signal peptide cleavage site to residue 246; the mature protein likely is defined by residues 247-360.

- 5 "Vgr-1(fx)" refers to proteins encoded by the murine Vgr-1 gene and defining the conserved seven cysteine skeleton (Seq. ID No. 12). The amino acid sequence for the full length protein appears in Lyons, et al, (1989), 86 PNAS 4554-4558. The prodomain likely extends from the signal peptide cleavage site to residue 299; the mature protein likely is defined by residues 300-438.
- 10 "GDF-1(fx)" refers to proteins encoded by the human GDF-1 gene and defining the conserved seven cysteine skeleton (Seq. ID No. 13). The cDNA and encoded amino sequence for the full length protein are provided in Seq. ID. Nos. 30 and 31. The prodomain likely extends from the signal peptide cleavage site to residue 214; the mature protein likely is defined by residues 215-372.
- 15 "60A" refers generically to morphogenically active proteins expressed from nucleic acid (e.g., the Drosophila 60A gene) encoding 60A protein or morphogenically active fragments thereof (see Seq. ID Nos. 23 and 24 wherein the cDNA and encoded amino acid sequence for the full length protein are provided). "60A(fx)" refers to the protein sequences defining the conserved seven cysteine skeleton (residues 354 to 455 of Seq. ID No. 24.) The prodomain likely extends from the signal peptide cleavage site to residue 324; the mature protein likely is defined by residues 325-455. The 60A protein is considered likely herein to be a phylogenetic counterpart variant of the human and mouse OP-1 genes; Sampath et al. (1993), 90 PNAS 6004-6008.
- 20
- 25 "BMP3(fx)" refers to proteins encoded by the human BMP3 gene and defining the conserved seven cysteine skeleton (Seq. ID No. 26). The amino acid sequence for the full length protein appears in Wozney et al. (1988), 242 Science 1528-1534. The prodomain likely extends from the signal peptide cleavage site to residue 290; the mature protein likely is defined by residues 291-472.

- 18 -

5 "BMP5(fx)" refers to proteins encoded by the human BMP5 gene and defining the conserved seven cysteine skeleton (Seq. ID No. 27). The amino acid sequence for the full length protein appears in Celeste, et al. (1991), 87 PNAS 9843-9847. The pro domain likely extends from the signal peptide cleavage site to residue 316; the mature protein likely is defined by residues 317-454.

"BMP6(fx)" refers to proteins encoded by the human BMP6 gene and defining the conserved seven cysteine skeleton (Seq. ID No. 28). The amino acid sequence for the full length protein appears in Celeste, et al. (1990), 87 PNAS 9843-5847. The pro domain likely includes extends from the signal peptide cleavage site to residue 374; the mature sequence likely includes residues 375-513.

10

As shown in FIGURE 2, the OP-2 and OP-3 proteins have an additional cysteine residue in the conserved C-terminal region (e.g., see residue 41 of Seq. ID Nos. 6 and 7), in addition to the conserved cysteine skeleton or domain in common with the other known proteins in this family. The GDF-1 protein has a four amino acid insert within the conserved skeleton (residues 44-47 of Seq. ID No. 13) but this insert likely does not interfere with the relationship of the cysteines in the folded structure. Further, the CBMP2 proteins are missing one amino acid residue within the cysteine skeleton. Thus, these morphogen polypeptides illustrate principles of alignment used herein with respect to the preferred reference morphogen sequence of human OP-1, residues 38-139 of Seq. ID No. 4.

15

20 In certain preferred embodiments, morphogens useful herein include those in which the amino acid sequences of morphogen polypeptides comprise a sequence sharing at least 70% amino acid sequence homology or "similarity", and preferably 80% homology or similarity with a reference morphogen selected from the foregoing naturally occurring morphogens. Preferably, the reference morphogen is human OP-1, and the reference sequence thereof is the C-terminal seven cysteine domain present in morphogenically active forms of human OP-1, residues 38-139 of Seq. ID No. 4. Morphogens useful herein accordingly include allelic, phylogenetic counterpart and other variants of the preferred reference sequence, whether naturally-occurring or biosynthetically produced (e.g., including "muteins" or "mutant proteins"), as well as novel members of the morphogenic family of proteins including the morphogens set forth and identified

25

- 19 -

above, e.g., in Table I. Certain particularly preferred morphogen polypeptides share at least 60% amino acid identity with the preferred reference sequence of human OP-1, still more preferably at least 65% amino acid identity therewith.

In other preferred embodiments, the family of morphogen polypeptides useful in the present invention, and members thereof, are defined by a generic amino acid sequence. For example, Generic Sequence 7 (Seq. ID No. 1) and Generic Sequence 8 (Seq. ID No. 2) disclosed below, accommodate the homologies shared among preferred morphogen protein family members identified to date, including at least OP-1, OP-2, OP-3, CBMP2A, CBMP2B, BMP3, 60A, DPP, Vg1, BMP5, BMP6, Vgr-1, and GDF-1 (Seq. ID Nos. 4-15, 24, and 26-29). The amino acid sequences for these proteins are described herein (see Sequence Listing) and/or in the art, as summarized above. The generic sequences include both the amino acid identity shared by these sequences in the C-terminal domain, defined by the six and seven cysteine skeletons (Generic Sequences 7 and 8, respectively), as well as alternative residues for the variable positions within the sequence. The generic sequences provide an appropriate cysteine skeleton where inter- or intramolecular disulfide bonds can form, and contain certain critical amino acids likely to influence the tertiary structure of the folded proteins. In addition, the generic sequences allow for an additional cysteine at position 41 (Generic Sequence 7) or position 46 (Generic Sequence 8), thereby encompassing the morphogenically active sequences of OP-2 and OP-3.

Generic Sequence 7

20

			Leu	Xaa	Xaa	Xaa	Phe	Xaa	Xaa
			1				5		
Xaa	Gly	Trp	Xaa	Xaa	Xaa	Xaa	Xaa	Xaa	Pro
		10					15		
Xaa	Xaa	Xaa	Xaa	Ala	Xaa	Tyr	Cys	Xaa	Gly
		20					25		
Xaa	Cys	Xaa	Xaa	Pro	Xaa	Xaa	Xaa	Xaa	Xaa
		30					35		
Xaa	Xaa	Xaa	Asn	His	Ala	Xaa	Xaa	Xaa	Xaa
		40					45		

- 20 -

Xaa	Xaa	Xaa	Xaa	Xaa	Xaa	Xaa	Xaa	Xaa	Xaa
		50					55		
Xaa	Xaa	Xaa	Cys	Cys	Xaa	Pro	Xaa	Xaa	Xaa
		60					65		
Xaa	Xaa	Xaa	Xaa	Xaa	Leu	Xaa	Xaa	Xaa	Xaa
		70					75		
Xaa	Xaa	Xaa	Val	Xaa	Leu	Xaa	Xaa	Xaa	Xaa
		80					85		
Xaa	Met	Xaa	Val	Xaa	Xaa	Cys	Xaa	Cys	Xaa
		90					95		

wherein each Xaa independently is selected from a group of one or more specified amino acids defined as follows: "Res." means "residue" and Xaa at res.2 = (Tyr or Lys); Xaa at res.3 = Val or Ile; Xaa at res.4 = (Ser, Asp or Glu); Xaa at res.6 = (Arg, Gln, Ser, Lys or Ala); Xaa at res.7 = (Asp or Glu); Xaa at res.8 = (Leu, Val or Ile); Xaa at res.11 = (Gln, Leu, Asp, His, Asn or Ser); Xaa at res.12 = (Asp, Arg, Asn or Glu); Xaa at res.13 = (Trp or Ser); Xaa at res.14 = (Ile or Val); Xaa at res.15 = (Ile or Val); Xaa at res.16 = (Ala or Ser); Xaa at res.18 = (Glu, Gln, Leu, Lys, Pro or Arg); Xaa at res.19 = (Gly or Ser); Xaa at res.20 = (Tyr or Phe); Xaa at res.21 = (Ala, Ser, Asp, Met, His, Gln, Leu or Gly); Xaa at res.23 = (Tyr, Asn or Phe); Xaa at res.26 = (Glu, His, Tyr, Asp, Gln, Ala or Ser); Xaa at res.28 = (Glu, Lys, Asp, Gln or Ala); Xaa at res.30 = (Ala, Ser, Pro, Gln, Ile or Asn); Xaa at res.31 = (Phe, Leu or Tyr); Xaa at res.33 = (Leu, Val or Met); Xaa at res.34 = (Asn, Asp, Ala, Thr or Pro); Xaa at res.35 = (Ser, Asp, Glu, Leu, Ala or Lys); Xaa at res.36 = (Tyr, Cys, His, Ser or Ile); Xaa at res.37 = (Met, Phe, Gly or Leu); Xaa at res.38 = (Asn, Ser or Lys); Xaa at res.39 = (Ala, Ser, Gly or Pro); Xaa at res.40 = (Thr, Leu or Ser); Xaa at res.44 = (Ile, Val or Thr); Xaa at res.45 = (Val, Leu, Met or Ile); Xaa at res.46 = (Gln or Arg); Xaa at res.47 = (Thr, Ala or Ser); Xaa at res.48 = (Leu or Ile); Xaa at res.49 = (Val or Met); Xaa at res.50 = (His, Asn or Arg); Xaa at res.51 = (Phe, Leu, Asn, Ser, Ala or Val); Xaa at res.52 = (Ile, Met, Asn, Ala, Val, Gly or Leu); Xaa at res.53 = (Asn, Lys, Ala, Glu, Gly or Phe); Xaa at res.54 = (Pro, Ser or Val); Xaa at res.55 = (Glu, Asp, Asn, Gly, Val, Pro or Lys); Xaa at res.56 = (Thr, Ala, Val, Lys, Asp, Tyr, Ser, Gly, Ile or His); Xaa at res.57 = (Val, Ala or Ile); Xaa at res.58 = (Pro or Asp); Xaa at res.59 = (Lys, Leu or Glu); Xaa at res.60 = (Pro, Val or Ala); Xaa

- 21 -

at res.63 = (Ala or Val); Xaa at res.65 = (Thr, Ala or Glu); Xaa at res.66 = (Gln, Lys, Arg or Glu); Xaa at res.67 = (Leu, Met or Val); Xaa at res.68 = (Asn, Ser, Asp or Gly); Xaa at res.69 = (Ala, Pro or Ser); Xaa at res.70 = (Ile, Thr, Val or Leu); Xaa at res.71 = (Ser, Ala or Pro); Xaa at res.72 = (Val, Leu, Met or Ile); Xaa at res.74 = (Tyr or Phe); Xaa at res.75 = (Phe, Tyr, Leu or His); Xaa at res.76 = (Asp, Asn or Leu); Xaa at res.77 = (Asp, Glu, Asn, Arg or Ser); Xaa at res.78 = (Ser, Gln, Asn, Tyr or Asp); Xaa at res.79 = (Ser, Asn, Asp, Glu or Lys); Xaa at res.80 = (Asn, Thr or Lys); Xaa at res.82 = (Ile, Val or Asn); Xaa at res.84 = (Lys or Arg); Xaa at res.85 = (Lys, Asn, Gln, His, Arg or Val); Xaa at res.86 = (Tyr, Glu or His); Xaa at res.87 = (Arg, Gln, Glu or Pro); Xaa at res.88 = (Asn, Glu, Trp or Asp); Xaa at res.90 = (Val, Thr, Ala or Ile); Xaa at res.92 = (Arg, Lys, Val, Asp, Gln or Glu); Xaa at res.93 = (Ala, Gly, Glu or Ser); Xaa at res.95 = (Gly or Ala) and Xaa at res.97 = (His or Arg).

Generic Sequence 8 (Seq. ID No. 2) includes all of Generic Sequence 7 and in addition includes the following sequence (Seq. ID No. 14) at its N-terminus:

Cys	Xaa	Xaa	Xaa	Xaa
1				5

Accordingly, beginning with residue 7, each "Xaa" in Generic Seq. 8 is a specified amino acid defined as for Generic Seq. 7, with the distinction that each residue number described for Generic Sequence 7 is shifted by five in Generic Seq. 8. Thus, "Xaa at res.2 = (Tyr or Lys)" in Gen. Seq. 7 refers to Xaa at res. 7 in Generic Seq. 8. In Generic Seq. 8, Xaa at res.2 = (Lys, Arg, Ala or Gln); Xaa at res.3 = (Lys, Arg or Met); Xaa at res.4 = (His, Arg or Gln); and Xaa at res.5 = (Glu, Ser, His, Gly, Arg, Pro, Thr, or Tyr).

As noted above, certain currently preferred morphogen polypeptide sequences useful in this invention have greater than 60% identity, preferably greater than 65% identity, with the amino acid sequence defining the preferred reference sequence of hOP-1. These particularly preferred sequences include allelic and phylogenetic counterpart variants of the OP-1 and OP-2 proteins, including the Drosophila 60A protein. Accordingly, in certain particularly preferred embodiments, useful morphogens include active proteins comprising pairs of polypeptide chains within the generic amino acid sequence herein referred to as "OPX" (Seq. ID No. 3), which

- 22 -

defines the seven cysteine skeleton and accommodates the homologies between several identified variants of OP1 and OP2. As described therein, each Xaa at a given position independently is selected from the residues occurring at the corresponding position in the C-terminal sequence of mouse or human OP1 or OP2 (see Seq. ID Nos. 4-7 and/or Seq. ID Nos. 15-22).

5 In still other preferred embodiments, useful morphogen polypeptides have amino acid sequences comprising a sequence encoded by nucleic acid that hybridizes, under stringent hybridization conditions, to DNA or RNA encoding reference morphogen sequences, e.g., C-terminal sequences defining the conserved seven cysteine domains of OP1 or OP2, e.g., nucleotides 1036-1341 and nucleotides 1390-1695 of Seq. ID No. 15 and 19, respectively. As
10 used herein, stringent hybridization conditions are defined as hybridization according to known techniques in 40% formamide, 5 X SSPE, 5 X Denhardt's Solution, and 0.1% SDS at 37°C overnight, and washing in 0.1 X SSPE, 0.1% SDS at 50°C.

As noted above, morphogens useful in the present invention generally are dimeric proteins comprising a folded pair of the above polypeptides. Morphogens are inactive when
15 reduced, but are active as oxidized homodimers and when oxidized in combination with other morphogens of this invention to produce heterodimers. Thus, members of a folded pair of morphogen polypeptides in a morphogenically active protein can be selected independently from any of the specific morphogen polypeptides mentioned above.

The morphogens useful in the methods, compositions and devices of this invention
20 include proteins comprising any of the polypeptide chains described above, whether isolated from naturally-occurring sources, or produced by recombinant DNA or other synthetic techniques, and includes allelic and phylogenetic counterpart variants of these proteins, as well as biosynthetic variants (muteins) thereof, and various truncated and fusion constructs. Deletion or addition mutants also are envisioned to be active, including those which may alter the conserved C-
25 terminal six or seven cysteine domain, provided that the alteration does not functionally disrupt the relationship of these cysteines in the folded structure. Accordingly, such active forms are considered the equivalent of the specifically described constructs disclosed herein. The proteins may include forms having varying glycosylation patterns, varying N-termini, a family of related

- 23 -

proteins having regions of amino acid sequence homology, and active truncated or mutated forms of native or biosynthetic proteins, produced by expression of recombinant DNA in host cells.

The morphogenic proteins can be expressed from intact or truncated cDNA or from synthetic DNAs in procaryotic or eucaryotic host cells, and purified, cleaved, refolded, and dimerized to form morphogenically active compositions. Currently preferred host cells include *E. coli* or mammalian cells, such as CHO, COS or BSC cells. A detailed description of the morphogens useful in the methods, compositions and devices of this invention is disclosed in copending U.S. Serial Nos. 07/752,764, filed August 30, 1991, and 07/667,724, filed March 11, 1991, the disclosures of which are incorporated by reference herein.

Thus, in view of this disclosure, skilled genetic engineers can isolate genes from cDNA or genomic libraries of various different biological species, which encode appropriate amino acid sequences, or construct DNAs from oligonucleotides, and then can express them in various types of host cells, including both procaryotes and eucaryotes, to produce large quantities of active proteins capable of stimulating the morphogenesis of, and/or inhibiting damage to, mammalian dental tissues.

As noted above, a protein is morphogenic herein generally if it induces the developmental cascade of cellular and molecular events that culminate in the formation of new, organ-specific tissue. Preferably, a morphogen comprises a pair of polypeptides having a sequence that corresponds to or is functionally equivalent to at least the conserved C-terminal six or seven cysteine skeleton of human OP-1, included in Seq. ID No. 4. The morphogens generally are competent to induce all of the following biological functions in a morphogenically permissive environment: stimulating proliferation of progenitor cells; stimulating the differentiation of progenitor cells; stimulating the proliferation of differentiated cells; and supporting the growth and maintenance of differentiated cells. Details of how the morphogens useful in this invention first were identified, as well as a description on how to make, use and test them for morphogenic activity are disclosed in U.S.S.Nos. 07/752,764 and 07/667,274. As disclosed therein, the morphogens can be purified from naturally-sourced material or recombinantly produced from procaryotic or eucaryotic host cells, using the genetic sequences disclosed therein. Alternatively, novel morphogenic sequences can be identified following the procedures disclosed therein.

- 24 -

Exemplary useful morphogens include naturally derived proteins comprising a pair of polypeptides, the amino acid sequences of which comprise one or more of the sequences disclosed in the Sequence Listing and FIGURE 2. Other useful sequences include those of the naturally derived morphogens dorsalin-1 and GDF-5, discussed herein in connection with Table I, as well as biosynthetic constructs disclosed in U.S. Pat. 5,011,691, the disclosure of which is
5 incorporated herein by reference (e.g., COP-1, COP-3, COP-4, COP-5, COP-7, and COP-16).

Accordingly, certain preferred morphogens useful in the methods and compositions of this invention can be described as morphogenically active proteins having amino acid sequences sharing 70% or, preferably, 80% homology (similarity) with a reference morphogen sequence described above, e.g., residues 38-139 of Seq. ID No. 4, where "homology" is as defined herein
10 above. Alternatively, in other preferred embodiments, morphogens useful in the methods and compositions disclosed herein fall within the family of polypeptides described by Generic Sequence 7, Seq. ID No. 1, more preferably by Generic Sequence 8, Seq. ID No. 2.

FIGURE 2 herein sets forth an alignment of the amino acid sequences of the active regions of naturally occurring proteins that have been identified or appreciated herein as morphogens, including human OP-1 (hOP-1, Seq. ID Nos. 4 and 15-16), mouse OP-1 (mOP-1, Seq. ID Nos. 5 and 17-18), human and mouse OP-2 (Seq. ID Nos. 6, 7, and 19-22), mouse OP-3 (Seq. ID Nos. 25-26), CBMP2A (Seq. ID No. 8), CBMP2B (Seq. ID No. 9), BMP3 (Seq. ID No. 27), DPP (from Drosophila, Seq. ID No. 10), Vgl, (from Xenopus, Seq. ID No. 11), Vgr-1
15 (from mouse, Seq. ID No. 12), GDF-1 (from mouse and/or human, Seq. ID Nos. 13, 30 and 31), 60A protein (from Drosophila, Seq. ID Nos. 23 and 24), BMP5 (Seq. ID No. 28) and BMP6 (Seq. ID No. 29). The sequences are aligned essentially following the method of Needleman et al. (1970), 48 J. Mol. Biol., 443-453, calculated using the Align Program (DNASTar, Inc). In FIGURE 2, three dots indicates that the amino acid in that position is the same as the
20 corresponding amino acid in hOP-1. Three dashes indicates that no amino acid is present in that position, and are included for purposes of illustrating homologies. For example, amino acid residue 60 of CBMP-2A and CBMP-2B is "missing". Of course, both of these amino acid sequences in this region comprise Asn-Ser (residues 58, 59), with CBMP-2A then comprising Lys and Ile, whereas CBMP-2B comprises Ser and Ile. FIGURE 2 also illustrates the handling of
25 insertions in the morphogen amino acid sequence: between residues 56 and 57 of BMP3 is an
30

- 25 -

inserted Val residue; between residues 43 and 44 of GDF-1 is inserted the amino acid sequence, Gly-Gly-Pro-Pro. Such deviations from the reference morphogen sequence are ignored for purposes of calculating the defined relationship between, e.g., GDF-1 and hOP-1. As is apparent from the amino acid sequence comparisons set forth in FIGURE 4, significant amino acid changes
5 can be made from the reference sequence while retaining morphogenic activity. For example, while the GDF-1 protein sequence depicted in FIGURE 4 shares only about 50% amino acid identity with the hOP1 sequence described therein, the GDF-1 sequence shares greater than 70% amino acid sequence homology (or "similarity") with the hOP1 sequence, where "homology" or "similarity" includes allowed conservative amino acid substitutions within the aligned sequence,
10 e.g., as defined by Dayhoff et al., (1979) 5 Atlas of Protein Sequence and Structure Suppl. 3, pp.345-362, (M.O. Dayhoff, ed., Nat'l BioMed. Res. Fd'n, Washington D.C.).

The currently most preferred protein sequences useful as morphogens in this invention include those having greater than 60% identity, preferably greater than 65% identity, with the amino acid sequence defining the conserved six or seven cysteine skeleton of hOP1 (e.g., residues
15 43-139 or 38-139 of Seq. ID No. 5). These most preferred sequences include both allelic and phylogenetic counterpart variants of the OP-1 and OP-2 proteins, including the Drosophila 60A protein. Accordingly, in still another preferred aspect, the invention includes morphogens comprising species of polypeptide chains having the generic amino acid sequence referred to herein as "OPX", which defines the seven cysteine domain and accommodates the identities and
20 homologies between the various identified OP1 and OP2 proteins. OPX is presented in Seq. ID No. 3. As described therein, each Xaa at a given position independently is selected from the residues occurring at the corresponding position in the C-terminal sequence of mouse or human OP1 or OP2 (see FIGURE 2 and Seq. ID Nos. 4-7 and/or Seq. ID Nos. 15-22).

Alternatively, an effective amount of an agent competent to stimulate endogenous
25 morphogen levels in a mammal may be administered by any of the routes described herein. For example, an agent competent to stimulate morphogen production and/or secretion from periodontal tissue, gingiva, alveolar bone tissue in the tooth socket, or pulp tissue, may be provided to a mammal, e.g., by direct administration of the morphogen-stimulating agent to dental tissue. Alternatively, the morphogen-stimulating agent may induce morphogen expression and/
30 secretion at a distant site (e.g., at a tissue locus other than dental tissue), with the expressed

- 26 -

morphogen circulating to dental tissue competent to take up the morphogen and respond thereto. A method for identifying and testing agents competent to modulate the levels of endogenous morphogens in a given tissue is described in detail in prior related U.S.S.Nos. 07/938,021 and 07/752,859, the teachings of which are incorporated herein by reference. Briefly, candidate compounds can be identified and tested by incubation *in vitro* with a test tissue or cells thereof, or a cultured cell line derived therefrom, for a time sufficient to allow the compound to affect the production, i.e., the expression and/or secretion, of a morphogen produced by the cells of that tissue. Here, suitable tissue, or cultured cells of a suitable tissue, preferably can be selected from renal epithelium, dental fibroblasts, cementoblasts, odontoblasts and osteoblasts.

III. Formulations and Methods for Administration

The morphogens can be provided to a dental tissue surface, e.g., a dentinal or gingival surface, by any suitable means. Preferably, the morphogen, or a morphogen-stimulating agent, is provided directly to the tissue surface by topical administration. Alternatively, the morphogen can be provided to the tissue by, for example, local injection. While not currently preferred, systemic injection also may be a viable administration route under certain circumstances, such as to treat advanced or chronic disease states, or as a preventive measure in individuals at extreme risk of disease. A detailed description of considerations for systemic administration, including oral and parenteral administration, is disclosed, for example in U.S.S.No. 08/165,511, the teachings of which are incorporated herein by reference.

Where the morphogen is provided directly to a dentinal surface, it can be administered as part of a biocompatible formulation that may be a liquid, gel or solid. For example, it can be dispersed in an aqueous medium that does not impair the mammal's physiologic fluid or salt balance. The aqueous medium for the morphogen thus may comprise normal physiologic saline (0.85% or 0.15 M NaCl), pH 7.0-7.4. The aqueous morphogen formulation can be made, for example, by dissolving the morphogen in 50% ethanol containing acetonitrile in 0.1% trifluoroacetic acid (TFA) or 0.1% HCl, or equivalent solvents. One volume of the resultant solution then is added, for example, to ten volumes of phosphate buffered saline (PBS), which further can include 0.1-0.2% human serum albumin (HSA) or another acceptable carrier protein. The resultant solution preferably is vortexed extensively. The morphogen further can be

- 27 -

dispersed in and associated with a carrier capable of maintaining the morphogen at the administered locus. Useful formulations for some embodiments herein include viscous compositions and evaporative compositions. Biocompatible compositions that increase viscosity of the formulation include glycerol, polyalkylene glycols such as polyethylene glycol, oils of vegetable origin, hydrogenated naphthalenes, and the like. Useful evaporative compositions include physiologically acceptable, e.g., biologically inert, liquids that evaporate under physiological conditions so as to leave a residue of morphogen on the tissue surface. Evaporative liquids include low molecular weight organic or inorganic compounds such as water, ethanol, isopropanol, acetic acid and the like that do not adversely affect tissue function or tissue structural integrity prior to evaporating.

The formulation also can include an *in vivo* bioresorbable carrier material that acts as a controlled release delivery vehicle. Useful carriers can include biocompatible, preferably biodegradable structural components from, e.g., an extracellular matrix, such as collagen, laminin, hyaluronic acid, and the like, or polymeric materials, such as polylactic, polybutyric and polyglycolic acids. The carrier also can comprise an acellular tissue matrix, substantially depleted in nonstructural components, such as a demineralized, guanidine-extracted bone, dentine, periodontal ligament or cementum matrix. Details for preparing such matrices are disclosed in U.S.S.N. 07/752,764. Other useful controlled release carriers in which the morphogen can be dispersed are described in U.S. Pat. Nos. 4,975,526 and 4,919,939, the disclosures of which are incorporated herein by reference. Such carriers are envisioned to be particularly useful where the morphogen is used to seal a cavity.

Preferably, morphogen compositions that are viscous, evaporative or comprise a bioresorbable carrier are suitable for topical administration to a dentinal or gingival surface, and can inhibit recession or enhance regenerative healing of gingival tissue as well as stimulating morphogenesis of dentine tissue.

If desired, a given morphogen can be made more soluble in the aqueous composition by association with a suitable molecule. For example, the pro form of a morphogenic protein typically is more soluble or dispersible in physiological solutions than the corresponding mature form. In fact, endogenous morphogens are thought to be transported (e.g., secreted and

- 28 -

circulated) in the mammalian body in this form. This soluble form of the protein can be obtained from culture medium of morphogen-secreting mammalian cells e.g., cells transfected with nucleic acid encoding and competent to express the morphogen. Alternatively, a soluble species can be formulated by complexing the mature dimer (or an active fragment thereof) with a morphogen pro
5 domain or a solubility-enhancing fragment thereof (described more fully below). Other components, including various serum proteins, also can be useful to enhance morphogen solubility.

Finally, the morphogens or morphogen-stimulating agents provided herein can be administered alone or in combination with other molecules, particularly symptom alleviating
10 cofactors. Useful pharmaceutical cofactors for mitigating symptoms associated with damage to dental tissue include antiseptics, antibiotics, anaesthetics and analgesics. Preferred antiseptics for use in the present system include chlorhexidine and tbezonium iodide; preferred antibiotics include tetracycline, aminoglycosides such as neomycin, gentamycin, kanamycin, tobramycin, netilmicin, sisomicin, amikamycin, their sulfates or other derivatives, macrolides such as
15 erythromycin, its salts and other derivatives, spiramycin, josamycin or miocamycin, penicillins such as ampicillin, amoxicillin and the like, and cephalosporins, for example, cefaclor, cefadroxil, cefazolin, cefoperazone, cefotaxime, cephalothin, cefalexin, ceforanide, cefonicide or ceftriaxone. Preferred anaesthetics/analgesics include amide-type local anaesthetics such as lidocaine, mepivacaine, pyrocaine, bupivacaine, prilocaine, etidocaine, or other widely used anaesthetics
20 such as procaine.

Other cofactors include non-steroidal anti-inflammatory agents. However, the morphogens described herein themselves can modulate the body's inflammatory/immune response to an initial tissue injury. Specifically, and as described in detail in U.S.S.N. 08/165,511, in the presence of a morphogen, proinflammatory effector cells induced to migrate to a site of tissue
25 injury do not become significantly activated. Without being limited to any given theory, it is thought that, in the presence of the morphogen, damaged tissue is induced to undergo a recapitulation of tissue morphogenesis, where progenitor cells are induced to proliferate and differentiate in a tissue-specific manner, and new, functional, organized tissue is formed to replace the damaged or lost tissue, rather than disorganized, fibrous scar tissue.

- 29 -

The formulated compositions contain therapeutically effective amounts of the morphogen, e.g., amounts which provide appropriate concentrations of the morphogen to the dentinal surface for a time sufficient to stimulate morphogenesis of dentine and/or production of dentine matrix apposite thereto. As will be appreciated by those skilled in the art, the concentration of the compounds described in a therapeutic composition of the present invention will vary depending upon a number of factors, including the biological efficacy of the selected morphogen, the chemical characteristics (e.g., hydrophobicity) of the compounds employed, the formulation of the compound excipients, the administration route, and the treatment envisioned, including whether reparative dentine is to be induced at a distance, e.g., up to about 0.5mm, from the site of application. The preferred dosage to be administered also is likely to depend on such variables such as the condition of the dental tissues particularly of the dentinal surface to which morphogen is to be applied, the size of the tooth or dentinal surface to be treated, extent of dental tissue loss or recession, and the overall health status of the particular patient. In general, 0.00001-1000 mg of morphogen are sufficient with 0.0001-100 mg being preferable and 0.001 to 10 mg being even more preferable for primate teeth, including human teeth. No obvious morphogen induced pathological lesions arise when mature morphogen (e.g., OP-1, 20 mg) is administered daily to normal growing rats for 21 consecutive days. Moreover, 10 mg systemic injections of morphogen (e.g., OP-1) injected daily for 10 days into normal newborn mice do not produce any gross abnormalities.

Practice of the invention, including additional preferred aspects and embodiments thereof, will be still more fully understood from the following examples, which are presented herein for illustration only and should not be construed as limiting the invention in any way.

IV. Examples

Example 1: Morphogen-Induced Dentinogenesis in Mammalian Teeth

The following studies demonstrate the efficacy of morphogens in inducing dentine tissue morphogenesis in model mammals. Human dental pulp has been observed to respond unpredictably to injury. Currently, this represents a basic clinical problem in dentistry. Accordingly, primates are used herein as model mammals for demonstration of dentine

- 30 -

regeneration. Those skilled in the dental arts will understand and appreciate the correlation between human and nonhuman primate dental biology.

Recombinant human osteogenic protein-1 (hOP-1, Seq. ID No. 4), when applied to freshly cut primate residual dentine, stimulated significantly more reparative dentine formation
5 than calcium hydroxide paste (a conventional treatment). The response to OP-1 was dependent upon the concentration applied to the tooth as a cavity liner as well as the thickness of the residual dentine. The response to calcium hydroxide similarly was dependent upon the thickness of residual dentine.

Dentine matrices have been shown to contain bone morphogenetic protein (BMP)
10 activity (Bang and Urist (1967), 94 *Arch. Surg.* 781-789; Youmans and Urist (1967), 12 *Arch. Oral. Biol.* 999-1008; Butler *et al.* (1977), 56 *J. Dent. Res.* 288-232; Bessho *et al.* (1990), 70 *J. Dent. Res.* 171-175), growth factors (Finkleman *et al.* (1990), 5 *J. Bone Min. Res.* 717-723) and dentinogenic activity (Anneroth and Bang (1972), 23 *Odont. Rev.* 315-328; Nakashima, M. (1989), 5 *Endodont. Dent. Traumat.* 279-286; Nakashima, M. (1990), 35 *Arch. Oral. Biol.* 493-
15 497; Nakashima, M. (1990), 35 *Arch. Oral. Biol.* 277-281; Tziafas and Kolokuris (1990), 69 *J. Dent. Res.* 75-81; Tziafas *et al.* (1992), 37 *Arch. Oral. Biol.* 119-128; Smith *et al.* (1994), 39 *Arch. Oral. Biol.* 13-22). Impure extracts of dentine with BMP activity (Nakashima, M. (1990), 35 *Arch. Oral. Biol.* 493-497; Nakashima, M. (1990), 35 *Arch. Oral. Biol.* 277-281), recombinant BMP-2, and BMP-4 (Nakashima, M. (1994), 73 *J. Dent. Res.* 1515-1522) and
20 recombinant human osteogenic protein-1 (OP-1, BMP-7) (Rutherford *et al.* (1993), 38 *Arch. Oral. Biol.* 571-576; Rutherford *et al.* (1994), 39 *Arch. Oral. Biol.* 833-838) induce reparative dentineogenesis when placed on partially amputated pulps in mature adult teeth, see also U.S.S.Nos. 07/752,764 and 08/155,343, both incorporated by reference herein. In addition, dental pulps (Vaino *et al.* (1993), 75 *Cell.* 45-58; Heikinheimo, H. (1994), 73 *J. Dent. Res.* 590-
25 597) or cells derived from dental pulps (Takeda *et al.* (1994), 15 *Bone* 467-470) differentially express some morphogen genes. Accordingly, the present study explored whether solubilized OP-1 induced dentine formation when placed on freshly cut dentine surfaces in monkey permanent teeth.

- 31 -

Ninety (90) incisor, premolar and molar permanent teeth were anesthetized with Carbocaine (Cook-Waite) without vasoconstrictor, isolated by rubber dam, cleaned with a coolant. The variation in the area of the pulpal floors was less than 10% and the mean thickness of the residual floor dentine varied from approximately 0.1 to 0.9 mm between different teeth (as measured histomorphometrically). The pulpal floors were covered a fixed volume of an evaporative solution containing 0.01, 0.1, 1 or 10µg OP-1 in acid-alcohol (28.5% ethanol, 0.025% HCL), acid-alcohol alone, a thin layer of calcium hydroxide paste (Dycal, L.D. Caulk, Wilmington DE) or filled without a liner (no treatment). The cavities were filled with Ketac Silver (ESPE-Premier, Norristown, PA) according to standard reconstructive techniques. It will be recognized that any standard dental reconstructive material could be used. The animals were euthanized two months following surgery, specimens obtained and analyzed as described in the literature (Rutherford *et al.* (1993), 38 *Arch. Oral. Biol.* 571-576, incorporated herein by reference).

All procedures described above and involving animals were approved by and performed in an accredited animal care facility with extensive experience managing non-human primates. These studies were conducting using 5 adolescent (mixed dentition) male *Macaca fascicularis* of approximately 4-6 kg each. Dental procedures were performed on animals heavily sedated with, e.g., ketamine (15 mg/kg body wt.) and acepromazine (0.55 mg/kg body wt) supplemented with local intraoral infiltration anesthesia (without vasoconstrictor).

The variable amounts of reparative dentine observed in this study typically were limited in area to the dentinal surface transverse to the luminae of cut dentinal canaliculi. FIGURE 3 is a digitized video image of a typical tissue section prepared from an OP-1 treated animal by standard histological techniques. FIGURE 3 shows that reparative dentine formed deep to those dentinal canaliculi cut during preparation of the tooth. In most cases, the reparative dentine was present in all sections in which both the pulpal floor of the cavity preparation and the subjacent pulp chamber were evident. The spatial relationship of the mass of reparative dentine to the pulpal floor appeared to be governed by the orientation of the dentinal canaliculi to the long axis of the tooth and to the surface area of cut dentine intersecting the canaliculi. This spatial orientation suggests that OP-1 diffused through the dentinal canaliculi.

- 32 -

Indeed, the area of new dentine formation two months after morphogen treatment further depended on the dose of OP-1 applied. FIGURE 4 shows histomorphometric results illustrating this relationship. The mean thickness of the residual dentine was determined by averaging three separate and representative histomorphometric measurements in each of 5 sections distributed over 75% of the surface area of the cavity preparation. In FIGURE 4, the mean area of reparative dentine was determined by averaging three replicate histomorphometric measurements in each of five (5) tissue sections distributed over 75% of the surface area of the cavity preparation. In contrast, there were no significant differences between the amount of reparative dentine deep to the cut dentinal canaliculi in teeth to which no liners were applied (no treatment) and those treated with evaporative carrier alone.

As shown in FIGURES 5 and 6, equivalent amounts of OP-1 (e.g., 10 μ g in fixed equivalent volumes per tooth) stimulated significantly more reparative dentine two months after treatment than all other treatments attempted, including calcium hydroxide. The degree of stimulation related to the thickness of residual dentine separating the site of morphogen application from the pulp chamber wall, and became particularly evident as the thickness of residual dentine approached 0.2 mm. Each graphed residual dentine value (0.2, 0.45, 0.75 and 0.9 mm) represents a group of calculated values which ranged up to ± 0.15 mm. Thus, the area of reparative dentine present two (2) months after lining the cavities with 10 μ g OP-1, a thin layer of calcium hydroxide, or evaporative carrier alone is expressible as a function of the thickness of the residual dentine remaining in the pulpal floor. More reparative dentine was present in OP-1 treated than calcium hydroxide treated teeth (ANOVA, Scheffe's F, $P < 0.05$), in calcium hydroxide than carrier treated teeth ($P < 0.05$), and in OP-1 than carrier treated teeth ($P < 0.01$). OP-1 at 1 μ g and calcium hydroxide were equipotent over the range of thicknesses of residual dentine (not shown). Smaller amounts of OP-1 were poorly effective in cavities of the size assessed in this study.

Resection of the dentinal canaliculi may result in odontoblast death, particularly in the deeper preparations (Lee *et al.* (1992), *AM. J. Den.* 64-68). However, it is possible that the tooth preparation procedure utilized preserved odontoblasts even in the deepest preparations (Smith *et al.* (1994), *39 Arch. Oral. Biol.* 13-22). Hence, the dentine formed in these studies may be reactionary dentine, formed by stimulation of the phenotypic function the original odontoblasts,

- 33 -

or reparative dentine formed by newly differentiated cells deep to the lost odontoblasts (Lesot *et al.* (1993), 3 *Cells and Materials* 201-217; Smith *et al.* (1994), 39 *Arch. Oral. Biol.* 13-22). The design utilized in these studies did not permit temporal observations of the odontoblast layer deep to the cut dentinal canaliculi. Earlier studies demonstrated the capacity of OP-1 complexed to an insoluble collagen-based carrier to stimulate reparative dentine when placed directly upon partially amputated pulps (U.S.S.N. 08/155,343 and Rutherford *et al.* (1993), 38 *Arch. Oral. Biol.* 571-576; Rutherford *et al.* (1994), 39 *Arch. Oral. Biol.* 833-838). Partial pulp amputation obviously removes the layer of odontoblasts, exposing the deeper fibrous connective tissue of the pulp. Human pulp cells are responsive to OP-1 *in vitro*, further suggesting that pulp itself contains responsive (competent) cells. The specific phenotypes of these OP-1 responsive pulp cells have not yet been identified conclusively.

Example 2. Preparation of Soluble Morphogen Complexes useful in Stimulating Dentineogenesis

A currently preferred form of the morphogen useful herein, having improved solubility in aqueous solutions, is a dimeric morphogenic protein comprising at least the C-terminal seven cysteine domain characteristic of the morphogen family, complexed with a peptide comprising a pro region of a member of the morphogen family, or a solubility-enhancing fragment thereof, or an allelic, species or other sequence variant thereof. Preferably, the dimeric morphogenic protein is complexed with two pro region peptides. Also, the dimeric morphogenic protein preferably is noncovalently complexed with the pro region peptides. The pro region peptides preferably comprise at least the N-terminal eighteen amino acids that define the pro domain of a given naturally occurring morphogen, or an allelic or phylogenetic counterpart variant thereof. In their preferred embodiments, peptides defining substantially the full length pro domain are used.

Other soluble forms of morphogens include dimers of the uncleaved pro forms of these proteins, as well as "hemi-dimers" wherein one subunit of the dimer is an uncleaved pro form of the protein, and the other subunit comprises the mature form of the protein, including truncated forms thereof, preferably noncovalently associated with a cleaved pro domain peptide.

As described above and in U.S.S.N. 08/040,510, the teachings of which are incorporated herein by reference, useful pro domains include the full length pro regions, as well as

various truncated forms hereof, particularly truncated forms cleaved at proteolytic Arg-Xaa-Xaa-Arg (Seq. ID No. 32) cleavage sites within the pro domain polypeptide. For example, in OP-1, possible pro sequences include sequences defined by residues 30-292 (full length form); 48-292; and 158-292. Soluble OP-1 complex stability is best enhanced when the pro region comprises
5 the full length form rather than a truncated form, such as the residues 48-292 truncated form, in that residues 30-47 show sequence homology to the N-terminal portions of other morphogens, and currently are believed to have particular utility in enhancing complex stability for all morphogens. Accordingly, currently preferred pro domains include peptides comprising at least the N-terminal fragment, e.g., amino acid residues 30-47 of a naturally occurring morphogen
10 pro domain, or a biosynthetic variant thereof that retains the solubility and/or stability enhancing properties of the naturally-occurring peptide.

As will be appreciated by those having ordinary skill in the art, useful sequences encoding the pro region can be obtained from genetic sequences encoding known morphogens. Alternatively, chimeric pro regions can be constructed from the sequences of one or more known
15 morphogens. Still another option is to create a synthetic sequence variant of one or more known pro region sequences.

In another preferred aspect, useful pro region peptides include polypeptide chains comprising an amino acid sequence encoded by a nucleic acid that hybridizes under stringent conditions with a DNA or RNA sequence encoding at least the N-terminal eighteen amino acids
20 of the pro region sequence for OP1 or OP2, e.g., nucleotides 136-192 and 152-211 of Seq. ID No. 15 and 19, respectively.

2.1 Isolation of soluble morphogen complex from conditioned media or body fluid

Morphogens are expressed from mammalian cells as soluble complexes. Typically,
25 however the complex is disassociated during purification, generally by exposure to denaturants often added to the purification solutions, such as detergents, alcohols, organic solvents, chaotropic agents and compounds added to reduce the pH of the solution. Provided below is a currently preferred protocol for purifying the soluble proteins from conditioned media (or, optionally, a body fluid such as serum, cerebrospinal or peritoneal fluid), under non-denaturing
30

- 35 -

conditions. The method is rapid, reproducible and yields isolated soluble morphogen complexes in substantially pure form.

Soluble morphogen complexes can be isolated from conditioned media using a simple, three step chromatographic protocol performed in the absence of denaturants. The protocol involves running the media (or body fluid) over an affinity column, followed by ion exchange and gel filtration chromatographies. The affinity column described below is a Zn-IMAC column. The present protocol has general applicability to the purification of a variety of morphogens, all of which are anticipated to be isolatable using only minor modifications of the protocol described below. An alternative protocol also envisioned to have utility includes an immunoaffinity column, created using standard procedures and, for example, using antibody specific for a given morphogen pro domain (complexed, for example, to a protein A-conjugated Sepharose column). Protocols for developing immunoaffinity columns are well described in the art, (see, for example, Guide to Protein Purification, M. Deutscher, ed., Academic Press, San Diego, 1990, particularly sections VII and XI thereof).

In this study, OP-1 was expressed in mammalian (CHO, chinese hamster ovary) cells as described in the art (see, for example, international application US90/05903 (WO91/05802)). The CHO cell conditioned media containing 0.5% FBS was initially purified using Immobilized Metal-Ion Affinity Chromatography (IMAC). The soluble OP-1 complex from conditioned media binds very selectively to the Zn-IMAC resin and a high concentration of imidazole (50 mM imidazole, pH 8.0) is required for the effective elution of the bound complex. The Zn-IMAC step separates the soluble OP-1 from the bulk of the contaminating serum proteins that elute in the flowthrough and 35 mM imidazole wash fractions. The Zn-IMAC purified soluble OP-1 is next applied to an S-Sepharose cation-exchange column equilibrated in 20 mM NaPO₄ (pH 7.0) with 50 mM NaCl. This S-Sepharose step serves to further purify and concentrate the soluble OP-1 complex in preparation for the following gel filtration step. The protein was applied to a Sephacryl S-200HR column equilibrated in TBS. Using substantially the same protocol, soluble morphogens also can be isolated from one or more body fluids, including serum, cerebrospinal fluid or peritoneal fluid.

IMAC was performed using Chelating-Sepharose (Pharmacia) that had been charged with three column volumes of 0.2 M ZnSO₄. The conditioned media was titrated to pH 7.0 and

- 36 -

applied directly to the ZN-IMAC resin equilibrated in 20 mM HEPES (pH 7.0) with 500 mM NaCl. The Zn-IMAC resin was loaded with 80 mL of starting conditioned media per mL of resin. After loading, the column was washed with equilibration buffer and most of the contaminating proteins were eluted with 35 mM imidazole (pH 7.0) in equilibration buffer. The soluble OP-1 complex then is eluted with 50 mM imidazole (pH 8.0) in 20 mM HEPES and 500 mM NaCl.

The 50 mM imidazole eluate containing the soluble OP-1 complex was diluted with nine volumes of 20 mM NaPO₄ (pH 7.0) and applied to an S-Sepharose (Pharmacia) column equilibrated in 20 mM NaPO₄ (pH 7.0) with 50 mM NaCl. The S-Sepharose resin was loaded with an equivalent of 800 mL of starting conditioned media per mL of resin. After loading the S-Sepharose column was washed with equilibration buffer and eluted with 100 mM NaCl followed by 300 mM and 500 mM NaCl in 20 mM NaPO₄ (pH 7.0). The 300 mM NaCl pool was further purified using gel filtration chromatography. Fifty mls of the 300 mM NaCl eluate was applied to a 5.0 X 90 cm Sephacryl S-200HR (Pharmacia) equilibrated in Tris buffered saline (TBS), 50 mM Tris, 150 mM NaCl (pH 7.4). The column was eluted at a flow rate of 5 mL/minute collecting 10 mL fractions. The apparent molecular of the soluble OP-1 was determined by comparison to protein molecular weight standards (alcohol dehydrogenase (ADH, 150 kDa), bovine serum albumin (BSA, 68 kDa), carbonic anhydrase (CA, 30 kDa) and cytochrome C (cyt C, 12.5 kDa). The purity of the S-200 column fractions was determined by separation on standard 15% polyacrylamide SDS gels stained with coomassie blue. The identity of the mature OP-1 and the pro-domain was determined by N-terminal sequence analysis after separation of the mature OP-1 from the pro-domain using standard reverse phase C18 HPLC.

The soluble OP-1 complex elutes with an apparent molecular weight of 110 kDa. This agrees well with the predicted composition of the soluble OP-1 complex with one mature OP-1 dimer (35-36 kDa) associated with two pro-domains (39 kDa each). Purity of the final complex can be verified by running the appropriate fraction in a reduced 15% polyacrylamide gel.

The complex components can be verified by running the complex-containing fraction from the S-200 or S-200HR columns over a reverse phase C18 HPLC column and eluting in an acetonitrile gradient (in 0.1% TFA), using standard procedures. The complex is dissociated by this step, and the pro domain and mature species elute as separate species. These separate species

- 37 -

then can be subjected to N-terminal sequencing using standard procedures (see, for example, Guide to Protein Purification, M. Deutscher, ed., Academic Press, San Diego, 1990, particularly pp. 602-613), and the identity of the isolated 36kD, 39kDa proteins confirmed as mature morphogen and isolated, cleaved pro domain, respectively. N-terminal sequencing of the isolated pro domain from mammalian cell produced OP-1 revealed 2 forms of the pro region, the intact form (beginning at residue 30 of Seq. ID No. 16) and a truncated form, (beginning at residue 48 of Seq. ID No. 16.) N-terminal sequencing of the polypeptide subunit of the isolated mature species reveals a range of N-termini for the mature sequence, beginning at residues 293, 300, 313, 315, 316, and 318, of Seq. ID No. 16, all of which are active as demonstrated by the standard bone morphogenesis assay set forth in U.S.S.N. 07/752,764 as incorporated herein by reference.

2.2 *In Vitro* Soluble Morphogen Complex Formation

As an alternative to purifying soluble complexes from culture media or a body fluid, soluble complexes can be formulated from purified pro domains and mature dimeric species. Successful complex formation apparently requires association of the components under denaturing conditions sufficient to relax the folded structure of these molecules, without affecting disulfide bonds. Preferably, the denaturing conditions mimic the environment of an intracellular vesicle sufficiently such that the cleaved pro domain has an opportunity to associate with the mature dimeric species under relaxed folding conditions. The concentration of denaturant in the solution then is decreased in a controlled, preferably step-wise manner, so as to allow proper refolding of the dimer and pro regions while maintaining the association of the pro domain with the dimer. Useful denaturants include 4-6M urea or guanidine hydrochloride (GuHCl), in buffered solutions of pH 4-10, preferably pH 6-8. The soluble complex then is formed by controlled dialysis or dilution into a solution having a final denaturant concentration of less than 0.1-2M urea or GuHCl, preferably 1-2 M urea or GuHCl, which then preferably can be diluted into a physiological buffer. Protein purification/renaturing procedures and considerations are well described in the art, and details for developing a suitable renaturing protocol readily can be determined by one having ordinary skill in the art. One useful text on the subject is Guide to Protein Purification, M. Deutscher, ed., Academic Press, San Diego, 1990, particularly section V. Complex formation also may be aided by addition of one or more chaperone proteins.

- 38 -

2.3 Stability of Soluble Morphogen Complexes

The stability of the highly purified soluble morphogen complex in a physiological buffer, e.g., tris-buffered saline (TBS) and phosphate-buffered saline (PBS), can be enhanced by any of a number of means. Currently preferred is by means of a pro region that comprises at least the first 18 amino acids of the pro sequence (e.g., residues 30-47 of Seq. ID NO. 16 for OP-1), and preferably is the full length pro region. Residues 30-47 show sequence homology to the N-terminal portion of other morphogens and are believed to have particular utility in enhancing complex stability for all morphogens. Other useful means for enhancing the stability of soluble morphogen complexes include three classes of additives. These additives include basic amino acids (e.g., L-arginine, lysine and betaine); nonionic detergents (e.g., Tween 80 or Nonidet P-120); and carrier proteins (e.g., serum albumin and casein). Useful concentrations of these additives include 1-100 mM, preferably 10-70 mM, including 50 mM, basic amino acid, 0.01-1.0%, preferably 0.05-0.2%, including 0.1% (v/v) nonionic detergent, and 0.01-1.0%, preferably 0.05-0.2%, including 0.1% (w/v) carrier protein.

15

Equivalents

The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The foregoing embodiments are therefore to be considered in all respects illustrative rather than limiting on the invention described herein. Scope of the invention is thus indicated by the appended claims rather than by the foregoing description, and all changes which come within the meaning and range of equivalency of the claims are intended to be embraced therein.

20

SEQUENCE LISTING

(1) GENERAL INFORMATION:

(i) APPLICANT:

(A) NAME: CREATIVE BIOMOLECULES, INC
(B) STREET: 45 SOUTH STREET
(C) CITY: HOPKINTON
(D) STATE: MA
(E) COUNTRY: USA
(F) POSTAL CODE (ZIP): 01748
(G) TELEPHONE: 1-508-435-9001
(H) TELEFAX: 1-508-435-0454
(I) TELEX:

(ii) TITLE OF INVENTION: MORPHOGEN-INDUCED DENTINE REGENERATION

(iii) NUMBER OF SEQUENCES: 32

(iv) CORRESPONDENCE ADDRESS:

(A) ADDRESSEE: CREATIVE BIOMOLECULES, INC
(B) STREET: 45 SOUTH STREET
(C) CITY: HOPKINTON
(D) STATE: MA
(E) COUNTRY: USA
(F) ZIP: 01748

(v) COMPUTER READABLE FORM:

(A) MEDIUM TYPE: Floppy disk
(B) COMPUTER: IBM PC compatible
(C) OPERATING SYSTEM: PC-DOS/MS-DOS
(D) SOFTWARE: PatentIn Release #1.0, Version #1.30

(vi) CURRENT APPLICATION DATA:

(A) APPLICATION NUMBER:
(B) FILING DATE:
(C) CLASSIFICATION:

(viii) ATTORNEY/AGENT INFORMATION:

(A) NAME: FENTON, GILLIAN M
(B) REGISTRATION NUMBER: 36,508
(C) REFERENCE/DOCKET NUMBER: CRP-088PC

(ix) TELECOMMUNICATION INFORMATION:

(A) TELEPHONE: (617) 248-7000
(B) TELEFAX: (617) 248-7100

(2) INFORMATION FOR SEQ ID NO:1:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 97 amino acids
(B) TYPE: amino acid
(C) STRANDEDNESS:
(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(ix) FEATURE:

(A) NAME/KEY: Protein

SUBSTITUTE SHEET (RULE 26)

(B) LOCATION: 1..97

(D) OTHER INFORMATION: /label= Generic-Seq-7

/n te= "wherein each Xaa is independently selected from a group of one or more specified amino acids as defined in the specification."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:1:

```

Leu Xaa Xaa Xaa Phe Xaa Xaa Xaa Gly Trp Xaa Xaa Xaa Xaa Xaa Xaa
 1           5           10           15
Pro Xaa Xaa Xaa Xaa Ala Xaa Tyr Cys Xaa Gly Xaa Cys Xaa Xaa Pro
 20           25           30
Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Asn His Ala Xaa Xaa Xaa Xaa Xaa
 35           40           45
Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Cys Cys Xaa Pro
 50           55           60
Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Leu Xaa Xaa Xaa Xaa Xaa Xaa Xaa
 65           70           75           80
Val Xaa Leu Xaa Xaa Xaa Xaa Xaa Met Xaa Val Xaa Xaa Cys Xaa Cys
 85           90           95
Xaa

```

(2) INFORMATION FOR SEQ ID NO:2:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 102 amino acids

(B) TYPE: amino acid

(C) STRANDEDNESS:

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(ix) FEATURE:

(A) NAME/KEY: Protein

(B) LOCATION: 1..102

(D) OTHER INFORMATION: /label= Generic-Seq-8

/note= "wherein each Xaa is independently selected from a group of one or more specified amino acids as defined in the specification."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:2:

```

Cys Xaa Xaa Xaa Xaa Leu Xaa Xaa Xaa Phe Xaa Xaa Xaa Gly Trp Xaa
 1           5           10           15
Xaa Xaa Xaa Xaa Xaa Pro Xaa Xaa Xaa Xaa Ala Xaa Tyr Cys Xaa Gly
 20           25           30
Xaa Cys Xaa Xaa Pro Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Asn His Ala
 35           40           45

```

SUBSTITUTE SHEET (RULE 26)

```

Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa
 50                      55                      60

Xaa Cys Cys Xaa Pro Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Xaa Leu Xaa Xaa
65                      70                      75                      80

Xaa Xaa Xaa Xaa Xaa Val Xaa Leu Xaa Xaa Xaa Xaa Xaa Met Xaa Val
      85                      90                      95

Xaa Xaa Cys Xaa Cys Xaa
                100

```

(2) INFORMATION FOR SEQ ID NO:3:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 102 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(ix) FEATURE:

- (A) NAME/KEY: Protein
- (B) LOCATION: 1..102
- (D) OTHER INFORMATION: /label= OPX

/note= "wherein each Xaa is independently selected from a group of one or more specified amino acids as defined in the specification."

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:3:

```

Cys Xaa Xaa His Glu Leu Tyr Val Xaa Phe Xaa Asp Leu Gly Trp Xaa
 1                      5                      10                      15

Asp Trp Xaa Ile Ala Pro Xaa Gly Tyr Xaa Ala Tyr Tyr Cys Glu Gly
      20                      25                      30

Glu Cys Xaa Phe Pro Leu Xaa Ser Xaa Met Asn Ala Thr Asn His Ala
      35                      40                      45

Ile Xaa Gln Xaa Leu Val His Xaa Xaa Xaa Pro Xaa Xaa Val Pro Lys
      50                      55                      60

Xaa Cys Cys Ala Pro Thr Xaa Leu Xaa Ala Xaa Ser Val Leu Tyr Xaa
      65                      70                      75                      80

Asp Xaa Ser Xaa Asn Val Xaa Leu Xaa Lys Xaa Arg Asn Met Val Val
      85                      90                      95

Xaa Ala Cys Gly Cys His
                100

```

(2) INFORMATION FOR SEQ ID NO:4:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 139 amin acids

SUBSTITUTE SHEET (RULE 26)

- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: Homo sapiens
- (F) TISSUE TYPE: HIPPOCAMPUS

(ix) FEATURE:

- (A) NAME/KEY: Protein
- (B) LOCATION: 1..139
- (D) OTHER INFORMATION: /label= hOP1-MATURE

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:4:

```

Ser Thr Gly Ser Lys Gln Arg Ser Gln Asn Arg Ser Lys Thr Pro Lys
 1           5           10           15
Asn Gln Glu Ala Leu Arg Met Ala Asn Val Ala Glu Asn Ser Ser Ser
          20           25           30
Asp Gln Arg Gln Ala Cys Lys Lys His Glu Leu Tyr Val Ser Phe Arg
          35           40           45
Asp Leu Gly Trp Gln Asp Trp Ile Ile Ala Pro Glu Gly Tyr Ala Ala
 50           55           60
Tyr Tyr Cys Glu Gly Glu Cys Ala Phe Pro Leu Asn Ser Tyr Met Asn
 65           70           75           80
Ala Thr Asn His Ala Ile Val Gln Thr Leu Val His Phe Ile Asn Pro
          85           90           95
Glu Thr Val Pro Lys Pro Cys Cys Ala Pro Thr Gln Leu Asn Ala Ile
          100          105          110
Ser Val Leu Tyr Phe Asp Asp Ser Ser Asn Val Ile Leu Lys Lys Tyr
          115          120          125
Arg Asn Met Val Val Arg Ala Cys Gly Cys His
          130          135

```

(2) INFORMATION FOR SEQ ID NO:5:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 139 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: MURIDAE
- (F) TISSUE TYPE: EMBRYO

(ix) FEATURE:

- (A) NAME/KEY: Protein

SUBSTITUTE SHEET (RULE 26)

(B) LOCATION: 1..139

(D) OTHER INFORMATION: /label= mOP1-MATURE

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:5:

```

Ser Thr Gly Gly Lys Gln Arg Ser Gln Asn Arg Ser Lys Thr Pro Lys
1           5           10           15
Asn Gln Glu Ala Leu Arg Met Ala Ser Val Ala Glu Asn Ser Ser Ser
20           25           30
Asp Gln Arg Gln Ala Cys Lys Lys His Glu Leu Tyr Val Ser Phe Arg
35           40           45
Asp Leu Gly Trp Gln Asp Trp Ile Ile Ala Pro Glu Gly Tyr Ala Ala
50           55           60
Tyr Tyr Cys Glu Gly Glu Cys Ala Phe Pro Leu Asn Ser Tyr Met Asn
65           70           75           80
Ala Thr Asn His Ala Ile Val Gln Thr Leu Val His Phe Ile Asn Pro
85           90           95
Asp Thr Val Pro Lys Pro Cys Cys Ala Pro Thr Gln Leu Asn Ala Ile
100          105          110
Ser Val Leu Tyr Phe Asp Asp Ser Ser Asn Val Ile Leu Lys Lys Tyr
115          120          125
Arg Asn Met Val Val Arg Ala Cys Gly Cys His
130          135

```

(2) INFORMATION FOR SEQ ID NO:6:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 139 amino acids

(B) TYPE: amino acid

(C) STRANDEDNESS:

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(vi) ORIGINAL SOURCE:

(A) ORGANISM: HOMO SAPIENS

(F) TISSUE TYPE: HIPPOCAMPUS

(ix) FEATURE:

(A) NAME/KEY: Protein

(B) LOCATION: 1..139

(D) OTHER INFORMATION: /label= HOP2-MATURE

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:6:

```

Ala Val Arg Pro Leu Arg Arg Arg Gln Pro Lys Lys Ser Asn Glu Leu
1           5           10           15
Pro Gln Ala Asn Arg Leu Pro Gly Ile Phe Asp Asp Val His Gly Ser
20           25           30

```

SUBSTITUTE SHEET (RULE 26)

```

Asp Val Val Pro Lys Ala Cys Cys Ala Pro Thr Lys Leu Ser Ala Thr
      100                      105                      110
Ser Val Leu Tyr Tyr Asp Ser Ser Asn Asn Val Ile Leu Arg Lys His
      115                      120                      125
Arg Asn Met Val Val Lys Ala Cys Gly Cys His
      130                      135

```

(2) INFORMATION FOR SEQ ID NO:8:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 101 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: bovinæ

(ix) FEATURE:

- (A) NAME/KEY: Protein
- (B) LOCATION: 1..101
- (D) OTHER INFORMATION: /label= CBMP-2A-FX

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:8:

```

Cys Lys Arg His Pro Leu Tyr Val Asp Phe Ser Asp Val Gly Trp Asn
 1           5           10           15
Asp Trp Ile Val Ala Pro Pro Gly Tyr His Ala Phe Tyr Cys His Gly
      20           25           30
Glu Cys Pro Phe Pro Leu Ala Asp His Leu Asn Ser Thr Asn His Ala
      35           40           45
Ile Val Gln Thr Leu Val Asn Ser Val Asn Ser Lys Ile Pro Lys Ala
      50           55           60
Cys Cys Val Pro Thr Glu Leu Ser Ala Ile Ser Met Leu Tyr Leu Asp
      65           70           75           80
Glu Asn Glu Lys Val Val Leu Lys Asn Tyr Gln Asp Met Val Val Glu
      85           90           95
Gly Cys Gly Cys Arg
      100

```

(2) INFORMATION FOR SEQ ID NO:9:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 101 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

SUBSTITUTE SHEET (RULE 26)

(ii) MOLECULE TYPE: protein

(vi) ORIGINAL SOURCE:

(A) ORGANISM: HOMO SAPIENS

(F) TISSUE TYPE: hippocampus

(ix) FEATURE:

(A) NAME/KEY: Protein

(B) LOCATION: 1..101

(D) OTHER INFORMATION: /label= CBMP-2B-FX

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:9:

```

Cys Arg Arg His Ser Leu Tyr Val Asp Phe Ser Asp Val Gly Trp Asn
 1           5           10           15
Asp Trp Ile Val Ala Pro Pro Gly Tyr Gln Ala Phe Tyr Cys His Gly
          20           25           30
Asp Cys Pro Phe Pro Leu Ala Asp His Leu Asn Ser Thr Asn His Ala
          35           40           45
Ile Val Gln Thr Leu Val Asn Ser Val Asn Ser Ser Ile Pro Lys Ala
 50           55           60
Cys Cys Val Pro Thr Glu Leu Ser Ala Ile Ser Met Leu Tyr Leu Asp
65           70           75           80
Glu Tyr Asp Lys Val Val Leu Lys Asn Tyr Gln Glu Met Val Val Glu
          85           90           95
Gly Cys Gly Cys Arg
          100

```

(2) INFORMATION FOR SEQ ID NO:10:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 102 amino acids

(B) TYPE: amino acid

(C) STRANDEDNESS:

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(vi) ORIGINAL SOURCE:

(A) ORGANISM: DROSOPHILA MELANOGASTER

(ix) FEATURE:

(A) NAME/KEY: Protein

(B) LOCATION: 1..102

(D) OTHER INFORMATION: /label= DPP-FX

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:10:

```

Cys Arg Arg His Ser Leu Tyr Val Asp Phe Ser Asp Val Gly Trp Asp
 1           5           10           15
Asp Trp Ile Val Ala Pro Leu Gly Tyr Asp Ala Tyr Tyr Cys His Gly
          20           25           30

```

SUBSTITUTE SHEET (RULE 26)

```

Lys Cys Pro Phe Pro Leu Ala Asp His Phe Asn Ser Thr Asn His Ala
  35                      40                      45
Val Val Gln Thr Leu Val Asn Asn Asn Asn Pro Gly Lys Val Pro Lys
  50                      55                      60
Ala Cys Cys Val Pro Thr Gln Leu Asp Ser Val Ala Met Leu Tyr Leu
  65                      70                      75                      80
Asn Asp Gln Ser Thr Val Val Leu Lys Asn Tyr Gln Glu Met Thr Val
                      85                      90                      95
Val Gly Cys Gly Cys Arg
                      100

```

(2) INFORMATION FOR SEQ ID NO:11:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 102 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: XENOPUS

(ix) FEATURE:

- (A) NAME/KEY: Protein
- (B) LOCATION: 1..102
- (D) OTHER INFORMATION: /label= VGL-FX

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:11:

```

Cys Lys Lys Arg His Leu Tyr Val Glu Phe Lys Asp Val Gly Trp Gln
  1                      5                      10                      15
Asn Trp Val Ile Ala Pro Gln Gly Tyr Met Ala Asn Tyr Cys Tyr Gly
  20                      25                      30
Glu Cys Pro Tyr Pro Leu Thr Glu Ile Leu Asn Gly Ser Asn His Ala
  35                      40                      45
Ile Leu Gln Thr Leu Val His Ser Ile Glu Pro Glu Asp Ile Pro Leu
  50                      55                      60
Pro Cys Cys Val Pro Thr Lys Met Ser Pro Ile Ser Met Leu Phe Tyr
  65                      70                      75                      80
Asp Asn Asn Asp Asn Val Val Leu Arg His Tyr Glu Asn Met Ala Val
                      85                      90                      95
Asp Glu Cys Gly Cys Arg
                      100

```

(2) INFORMATION FOR SEQ ID NO:12:

SUBSTITUTE SHEET (RULE 26)

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 102 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS:
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(vi) ORIGINAL SOURCE:
 (A) ORGANISM: MURIDAE

(ix) FEATURE:
 (A) NAME/KEY: Protein
 (B) LOCATION: 1..102
 (D) OTHER INFORMATION: /label= VGR-1-FX

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:12:

Cys	Lys	Lys	His	Glu	Leu	Tyr	Val	Ser	Phe	Gln	Asp	Val	Gly	Trp	Gln
1				5					10					15	
Asp	Trp	Ile	Ile	Ala	Pro	Lys	Gly	Tyr	Ala	Ala	Asn	Tyr	Cys	Asp	Gly
			20					25					30		
Glu	Cys	Ser	Phe	Pro	Leu	Asn	Ala	His	Met	Asn	Ala	Thr	Asn	His	Ala
		35					40					45			
Ile	Val	Gln	Thr	Leu	Val	His	Val	Met	Asn	Pro	Glu	Tyr	Val	Pro	Lys
	50					55					60				
Pro	Cys	Cys	Ala	Pro	Thr	Lys	Val	Asn	Ala	Ile	Ser	Val	Leu	Tyr	Phe
65					70					75					80
Asp	Asp	Asn	Ser	Asn	Val	Ile	Leu	Lys	Lys	Tyr	Arg	Asn	Met	Val	Val
				85					90					95	
Arg	Ala	Cys	Gly	Cys	His										
					100										

(2) INFORMATION FOR SEQ ID NO:13:

(i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 106 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS:
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(vi) ORIGINAL SOURCE:
 (A) ORGANISM: Homo sapiens
 (F) TISSUE TYPE: brain

(ix) FEATURE:
 (A) NAME/KEY: Protein
 (B) LOCATION: 1..106
 (D) OTHER INFORMATION: /note= "GDF-1 (fx)"

SUBSTITUTE SHEET (RULE 26)

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:13:

```

Cys Arg Ala Arg Arg Leu Tyr Val Ser Phe Arg Glu Val Gly Trp His
1           5           10           15
Arg Trp Val Ile Ala Pro Arg Gly Phe Leu Ala Asn Tyr Cys Gln Gly
20           25           30
Gln Cys Ala Leu Pro Val Ala Leu Ser Gly Ser Gly Gly Pro Pro Ala
35           40           45
Leu Asn His Ala Val Leu Arg Ala Leu Met His Ala Ala Ala Pro Gly
50           55           60
Ala Ala Asp Leu Pro Cys Cys Val Pro Ala Arg Leu Ser Pro Ile Ser
65           70           75           80
Val Leu Phe Phe Asp Asn Ser Asp Asn Val Val Leu Arg Gln Tyr Glu
85           90           95
Asp Met Val Val Asp Glu Cys Gly Cys Arg
100          105

```

(2) INFORMATION FOR SEQ ID NO:14:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 5 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS:
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: peptide

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:14:

```

Cys Xaa Xaa Xaa Xaa
1           5

```

(2) INFORMATION FOR SEQ ID NO:15:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 1822 base pairs
 - (B) TYPE: nucleic acid
 - (C) STRANDEDNESS: single
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: HOMO SAPIENS
- (F) TISSUE TYPE: HIPPOCAMPUS

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 49..1341
- (C) IDENTIFICATION METHOD: experimental

SUBSTITUTE SHEET (RULE 26)

(D) OTHER INFORMATION: /function= "OSTEOGENIC PROTEIN"
 /product= "OP1"
 /evidence= EXPERIMENTAL
 /standard_name= "OP1"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:15:

GGTGCGGGCC CGGAGCCCGG AGCCCGGGTA GCGCGTAGAG CCGGCGCG ATG CAC GTG	57
Met His Val	
1	
CGC TCA CTG CGA GCT GCG GCG CCG CAC AGC TTC GTG GCG CTC TGG GCA	105
Arg Ser Leu Arg Ala Ala Ala Pro His Ser Phe Val Ala Leu Trp Ala	
5 10 15	
CCC CTG TTC CTG CTG CGC TCC GCC CTG GCC GAC TTC AGC CTG GAC AAC	153
Pro Leu Phe Leu Leu Arg Ser Ala Leu Ala Asp Phe Ser Leu Asp Asn	
20 25 30 35	
GAG GTG CAC TCG AGC TTC ATC CAC CGG CGC CTC CGC AGC CAG GAG CGG	201
Glu Val His Ser Ser Phe Ile His Arg Arg Leu Arg Ser Gln Glu Arg	
40 45 50	
CGG GAG ATG CAG CGC GAG ATC CTC TCC ATT TTG GGC TTG CCC CAC CGC	249
Arg Glu Met Gln Arg Glu Ile Leu Ser Ile Leu Gly Leu Pro His Arg	
55 60 65	
CCG CGC CCG CAC CTC CAG GGC AAG CAC AAC TCG GCA CCC ATG TTC ATG	297
Pro Arg Pro His Leu Gln Gly Lys His Asn Ser Ala Pro Met Phe Met	
70 75 80	
CTG GAC CTG TAC AAC GCC ATG GCG GTG GAG GAG GGC GGC GGG CCC GGC	345
Leu Asp Leu Tyr Asn Ala Met Ala Val Glu Glu Gly Gly Gly Pro Gly	
85 90 95	
GGC CAG GGC TTC TCC TAC CCC TAC AAG GCC GTC TTC AGT ACC CAG GGC	393
Gly Gln Gly Phe Ser Tyr Pro Tyr Lys Ala Val Phe Ser Thr Gln Gly	
100 105 110 115	
CCC CCT CTG GCC AGC CTG CAA GAT AGC CAT TTC CTC ACC GAC GCC GAC	441
Pro Pro Leu Ala Ser Leu Gln Asp Ser His Phe Leu Thr Asp Ala Asp	
120 125 130	
ATG GTC ATG AGC TTC GTC AAC CTC GTG GAA CAT GAC AAG GAA TTC TTC	489
Met Val Met Ser Phe Val Asn Leu Val Glu His Asp Lys Glu Phe Phe	
135 140 145	
CAC CCA CGC TAC CAC CAT CGA GAG TTC CGG TTT GAT CTT TCC AAG ATC	537
His Pro Arg Tyr His His Arg Glu Phe Arg Phe Asp Leu Ser Lys Ile	
150 155 160	
CCA GAA GGG GAA GCT GTC ACG GCA GCC GAA TTC CGG ATC TAC AAG GAC	585
Pro Glu Gly Glu Ala Val Thr Ala Ala Glu Phe Arg Ile Tyr Lys Asp	
165 170 175	
TAC ATC CGG GAA CGC TTC GAC AAT GAG ACG TTC CGG ATC AGC GTT TAT	633
Tyr Ile Arg Glu Arg Phe Asp Asn Glu Thr Phe Arg Ile Ser Val Tyr	
180 185 190 195	
CAG GTG CTC CAG GAG CAC TTG GGC AGG GAA TCG GAT CTC TTC CTG CTC	681
Gln Val Leu Gln Glu His Leu Gly Arg Glu Ser Asp Leu Phe Leu Leu	
200 205 210	

SUBSTITUTE SHEET (RULE 26)

GAC	AGC	CGT	ACC	CTC	TGG	GCC	TCG	GAG	GAG	GGC	TGG	CTG	GTG	TTT	GAC	729
Asp	Ser	Arg	Thr	Leu	Trp	Ala	Ser	Glu	Glu	Gly	Trp	Leu	Val	Phe	Asp	
			215					220					225			
ATC	ACA	GCC	ACC	AGC	AAC	CAC	TGG	GTG	GTC	AAT	CCG	CGG	CAC	AAC	CTG	777
Ile	Thr	Ala	Thr	Ser	Asn	His	Trp	Val	Val	Asn	Pro	Arg	His	Asn	Leu	
		230					235					240				
GGC	CTG	CAG	CTC	TCG	GTG	GAG	ACG	CTG	GAT	GGG	CAG	AGC	ATC	AAC	CCC	825
Gly	Leu	Gln	Leu	Ser	Val	Glu	Thr	Leu	Asp	Gly	Gln	Ser	Ile	Asn	Pro	
	245					250					255					
AAG	TTG	GCG	GGC	CTG	ATT	GGG	CGG	CAC	GGG	CCC	CAG	AAC	AAG	CAG	CCC	873
Lys	Leu	Ala	Gly	Leu	Ile	Gly	Arg	His	Gly	Pro	Gln	Asn	Lys	Gln	Pro	
260					265					270					275	
TTC	ATG	GTG	GCT	TTC	TTC	AAG	GCC	ACG	GAG	GTC	CAC	TTC	CGC	AGC	ATC	921
Phe	Met	Val	Ala	Phe	Phe	Lys	Ala	Thr	Glu	Val	His	Phe	Arg	Ser	Ile	
				280					285					290		
CGG	TCC	ACG	GGG	AGC	AAA	CAG	CGC	AGC	CAG	AAC	CGC	TCC	AAG	ACG	CCC	969
Arg	Ser	Thr	Gly	Ser	Lys	Gln	Arg	Ser	Gln	Asn	Arg	Ser	Lys	Thr	Pro	
			295					300					305			
AAG	AAC	CAG	GAA	GCC	CTG	CGG	ATG	GCC	AAC	GTG	GCA	GAG	AAC	AGC	AGC	1017
Lys	Asn	Gln	Glu	Ala	Leu	Arg	Met	Ala	Asn	Val	Ala	Glu	Asn	Ser	Ser	
		310					315					320				
AGC	GAC	CAG	AGG	CAG	GCC	TGT	AAG	AAG	CAC	GAG	CTG	TAT	GTC	AGC	TTC	1065
Ser	Asp	Gln	Arg	Gln	Ala	Cys	Lys	Lys	His	Glu	Leu	Tyr	Val	Ser	Phe	
	325					330					335					
CGA	GAC	CTG	GGC	TGG	CAG	GAC	TGG	ATC	ATC	GCG	CCT	GAA	GGC	TAC	GCC	1113
Arg	Asp	Leu	Gly	Trp	Gln	Asp	Trp	Ile	Ile	Ala	Pro	Glu	Gly	Tyr	Ala	
340					345					350					355	
GCC	TAC	TAC	TGT	GAG	GGG	GAG	TGT	GCC	TTC	CCT	CTG	AAC	TCC	TAC	ATG	1161
Ala	Tyr	Tyr	Cys	Glu	Gly	Glu	Cys	Ala	Phe	Pro	Leu	Asn	Ser	Tyr	Met	
			360					365						370		
AAC	GCC	ACC	AAC	CAC	GCC	ATC	GTG	CAG	ACG	CTG	GTC	CAC	TTC	ATC	AAC	1209
Asn	Ala	Thr	Asn	His	Ala	Ile	Val	Gln	Thr	Leu	Val	His	Phe	Ile	Asn	
			375					380					385			
CCG	GAA	ACG	GTG	CCC	AAG	CCC	TGC	TGT	GCG	CCC	ACG	CAG	CTC	AAT	GCC	1257
Pro	Glu	Thr	Val	Pro	Lys	Pro	Cys	Cys	Ala	Pro	Thr	Gln	Leu	Asn	Ala	
		390					395					400				
ATC	TCC	GTC	CTC	TAC	TTC	GAT	GAC	AGC	TCC	AAC	GTC	ATC	CTG	AAG	AAA	1305
Ile	Ser	Val	Leu	Tyr	Phe	Asp	Asp	Ser	Ser	Asn	Val	Ile	Leu	Lys	Lys	
	405					410					415					
TAC	AGA	AAC	ATG	GTG	GTC	CGG	GCC	TGT	GGC	TGC	CAC	TAGCTCCTCC				1351
Tyr	Arg	Asn	Met	Val	Val	Arg	Ala	Cys	Gly	Cys	His					
420					425					430						
GAGAATTCAG ACCCTTTGGG GCCAAGTTTT TCTGGATCCT CCATTGCTCG CCTTGGCCAG																1411
GAACCAGCAG ACCAACTGCC TTTTGTGAGA CCTTCCCCTC CCTATCCCCA ACTTTAAAGG																1471
TGTGAGAGTA TTAGGAAACA TGAGCAGCAT ATGGCTTTTG ATCAGTTTTT CAGTGGCAGC																1531

SUBSTITUTE SHEET (RULE 26)

```

ATCCAATGAA CAAGATCCTA CAAGCTGTGC AGGCAAAACC TAGCAGGAAA AAAAAACAAC      1591
GCATAAAGAA AAATGGCCGG GCCAGGTCAT TGGCTGGGAA GTCTCAGCCA TGCACGGACT      1651
CGTTTCCAGA GGTAATTATG AGCGCCTACC AGCCAGGCCA CCCAGCCGTG GGAGGAAGGG      1711
GGCGTGGCAA GGGGTGGGCA CATTGGTGTC TGTGCGAAAG GAAAATTGAC CCGGAAGTTC      1771
CTGTAATAAA TGTCACAATA AAACGAATGA ATGAAAAAAA AAAAAAAAAA A      1822

```

(2) INFORMATION FOR SEQ ID NO:16:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 431 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:16:

```

Met His Val Arg Ser Leu Arg Ala Ala Ala Pro His Ser Phe Val Ala
 1             5             10             15
Leu Trp Ala Pro Leu Phe Leu Leu Arg Ser Ala Leu Ala Asp Phe Ser
          20             25             30
Leu Asp Asn Glu Val His Ser Ser Phe Ile His Arg Arg Leu Arg Ser
          35             40             45
Gln Glu Arg Arg Glu Met Gln Arg Glu Ile Leu Ser Ile Leu Gly Leu
          50             55             60
Pro His Arg Pro Arg Pro His Leu Gln Gly Lys His Asn Ser Ala Pro
          65             70             75             80
Met Phe Met Leu Asp Leu Tyr Asn Ala Met Ala Val Glu Glu Gly Gly
          85             90             95
Gly Pro Gly Gly Gln Gly Phe Ser Tyr Pro Tyr Lys Ala Val Phe Ser
          100            105            110
Thr Gln Gly Pro Pro Leu Ala Ser Leu Gln Asp Ser His Phe Leu Thr
          115            120            125
Asp Ala Asp Met Val Met Ser Phe Val Asn Leu Val Glu His Asp Lys
          130            135            140
Glu Phe Phe His Pro Arg Tyr His His Arg Glu Phe Arg Phe Asp Leu
          145            150            155            160
Ser Lys Ile Pro Glu Gly Glu Ala Val Thr Ala Ala Glu Phe Arg Ile
          165            170            175
Tyr Lys Asp Tyr Ile Arg Glu Arg Phe Asp Asn Glu Thr Phe Arg Ile
          180            185            190
Ser Val Tyr Gln Val Leu Gln Glu His Leu Gly Arg Glu Ser Asp Leu
          195            200            205

```

SUBSTITUTE SHEET (RULE 26)

```

Phe Leu Leu Asp Ser Arg Thr Leu Trp Ala Ser Glu Glu Gly Trp Leu
210                               215                               220

Val Phe Asp Ile Thr Ala Thr Ser Asn His Trp Val Val Asn Pro Arg
225                               230                               235                               240

His Asn Leu Gly Leu Gln Leu Ser Val Glu Thr Leu Asp Gly Gln Ser
245                               250                               255

Ile Asn Pro Lys Leu Ala Gly Leu Ile Gly Arg His Gly Pro Gln Asn
260                               265                               270

Lys Gln Pro Phe Met Val Ala Phe Phe Lys Ala Thr Glu Val His Phe
275                               280                               285

Arg Ser Ile Arg Ser Thr Gly Ser Lys Gln Arg Ser Gln Asn Arg Ser
290                               295                               300

Lys Thr Pro Lys Asn Gln Glu Ala Leu Arg Met Ala Asn Val Ala Glu
305                               310                               315                               320

Asn Ser Ser Ser Asp Gln Arg Gln Ala Cys Lys Lys His Glu Leu Tyr
325                               330                               335

Val Ser Phe Arg Asp Leu Gly Trp Gln Asp Trp Ile Ile Ala Pro Glu
340                               345                               350

Gly Tyr Ala Ala Tyr Tyr Cys Glu Gly Glu Cys Ala Phe Pro Leu Asn
355                               360                               365

Ser Tyr Met Asn Ala Thr Asn His Ala Ile Val Gln Thr Leu Val His
370                               375                               380

Phe Ile Asn Pro Glu Thr Val Pro Lys Pro Cys Cys Ala Pro Thr Gln
385                               390                               395                               400

Leu Asn Ala Ile Ser Val Leu Tyr Phe Asp Asp Ser Ser Asn Val Ile
405                               410                               415

Leu Lys Lys Tyr Arg Asn Met Val Val Arg Ala Cys Gly Cys His
420                               425                               430

```

(2) INFORMATION FOR SEQ ID NO:17:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1873 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: MURIDAE
- (F) TISSUE TYPE: EMBRYO

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 104..1393
- (D) OTHER INFORMATION: /function= "OSTEOGENIC PROTEIN"

/product= "MOP1"

SUBSTITUTE SHEET (RULE 26)

/note= "MOP1 (CDNA)"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:17:

CTGCAGCAAG TGACCTCGGG TCGTGGACCG CTGCCCTGCC CCCTCCGCTG CCACCTGGGG	60
CGGCGCGGGC CCGGTGCCCC GGATCGCGCG TAGAGCCGGC GCG ATG CAC GTG CGC	115
Met His Val Arg	
1	
TCG CTG CGC GCT GCG GCG CCA CAC AGC TTC GTG GCG CTC TGG GCG CCT	163
Ser Leu Arg Ala Ala Ala Pro His Ser Phe Val Ala Leu Trp Ala Pro	
5 10 15 20	
CTG TTC TTG CTG CGC TCC GCC CTG GCC GAT TTC AGC CTG GAC AAC GAG	211
Leu Phe Leu Leu Arg Ser Ala Leu Ala Asp Phe Ser Leu Asp Asn Glu	
25 30 35	
GTG CAC TCC AGC TTC ATC CAC CGG CGC CTC CGC AGC CAG GAG CGG CGG	259
Val His Ser Ser Phe Ile His Arg Arg Leu Arg Ser Gln Glu Arg Arg	
40 45 50	
GAG ATG CAG CGG GAG ATC CTG TCC ATC TTA GGG TTG CCC CAT CGC CCG	307
Glu Met Gln Arg Glu Ile Leu Ser Ile Leu Gly Leu Pro His Arg Pro	
55 60 65	
CGC CCG CAC CTC CAG GGA AAG CAT AAT TCG GCG CCC ATG TTC ATG TTG	355
Arg Pro His Leu Gln Gly Lys His Asn Ser Ala Pro Met Phe Met Leu	
70 75 80	
GAC CTG TAC AAC GCC ATG GCG GTG GAG GAG AGC GGG CCG GAC GGA CAG	403
Asp Leu Tyr Asn Ala Met Ala Val Glu Glu Ser Gly Pro Asp Gly Gln	
85 90 95 100	
GGC TTC TCC TAC CCC TAC AAG GCC GTC TTC AGT ACC CAG GGC CCC CCT	451
Gly Phe Ser Tyr Pro Tyr Lys Ala Val Phe Ser Thr Gln Gly Pro Pro	
105 110 115	
TTA GCC AGC CTG CAG GAC AGC CAT TTC CTC ACT GAC GCC GAC ATG GTC	499
Leu Ala Ser Leu Gln Asp Ser His Phe Leu Thr Asp Ala Asp Met Val	
120 125 130	
ATG AGC TTC GTC AAC CTA GTG GAA CAT GAC AAA GAA TTC TTC CAC CCT	547
Met Ser Phe Val Asn Leu Val Glu His Asp Lys Glu Phe Phe His Pro	
135 140 145	
CGA TAC CAC CAT CGG GAG TTC CGG TTT GAT CTT TCC AAG ATC CCC GAG	595
Arg Tyr His His Arg Glu Phe Arg Phe Asp Leu Ser Lys Ile Pro Glu	
150 155 160	
GGC GAA CGG GTG ACC GCA GCC GAA TTC AGG ATC TAT AAG GAC TAC ATC	643
Gly Glu Arg Val Thr Ala Ala Glu Phe Arg Ile Tyr Lys Asp Tyr Ile	
165 170 175 180	
CGG GAG CGA TTT GAC AAC GAG ACC TTC CAG ATC ACA GTC TAT CAG GTG	691
Arg Glu Arg Phe Asp Asn Glu Thr Phe Gln Ile Thr Val Tyr Gln Val	
185 190 195	
CTC CAG GAG CAC TCA GGC AGG GAG TCG GAC CTC TTC TTG CTG GAC AGC	739
Leu Gln Glu His Ser Gly Arg Glu Ser Asp Leu Phe Leu Leu Asp Ser	
200 205 210	

SUBSTITUTE SHEET (RULE 26)

CGC ACC ATC TGG GCT TCT GAG GAG GGC TGG TTG GTG TTT GAT ATC ACA	787
Arg Thr Ile Trp Ala Ser Glu Glu Gly Trp Leu Val Phe Asp Ile Thr	
215 220 225	
GCC ACC AGC AAC CAC TGG GTG GTC AAC CCT CGG CAC AAC CTG GGC TTA	835
Ala Thr Ser Asn His Trp Val Val Asn Pro Arg His Asn Leu Gly Leu	
230 235 240	
CAG CTC TCT GTG GAG ACC CTG GAT GGG CAG AGC ATC AAC CCC AAG TTG	883
Gln Leu Ser Val Glu Thr Leu Asp Gly Gln Ser Ile Asn Pro Lys Leu	
245 250 255 260	
GCA GGC CTG ATT GGA CGG CAT GGA CCC CAG AAC AAG CAA CCC TTC ATG	931
Ala Gly Leu Ile Gly Arg His Gly Pro Gln Asn Lys Gln Pro Phe Met	
265 270 275	
GTG GCC TTC TTC AAG GCC ACG GAA GTC CAT CTC CGT AGT ATC CGG TCC	979
Val Ala Phe Phe Lys Ala Thr Glu Val His Leu Arg Ser Ile Arg Ser	
280 285 290	
ACG GGG GGC AAG CAG CGC AGC CAG AAT CGC TCC AAG ACG CCA AAG AAC	1027
Thr Gly Gly Lys Gln Arg Ser Gln Asn Arg Ser Lys Thr Pro Lys Asn	
295 300 305	
CAA GAG GCC CTG AGG ATG GCC AGT GTG GCA GAA AAC AGC AGC AGT GAC	1075
Gln Glu Ala Leu Arg Met Ala Ser Val Ala Glu Asn Ser Ser Ser Asp	
310 315 320	
CAG AGG CAG GCC TGC AAG AAA CAT GAG CTG TAC GTC AGC TTC CGA GAC	1123
Gln Arg Gln Ala Cys Lys Lys His Glu Leu Tyr Val Ser Phe Arg Asp	
325 330 335 340	
CTT GGC TGG CAG GAC TGG ATC ATT GCA CCT GAA GGC TAT GCT GCC TAC	1171
Leu Gly Trp Gln Asp Trp Ile Ile Ala Pro Glu Gly Tyr Ala Ala Tyr	
345 350 355	
TAC TGT GAG GGA GAG TGC GCC TTC CCT CTG AAC TCC TAC ATG AAC GCC	1219
Tyr Cys Glu Gly Glu Cys Ala Phe Pro Leu Asn Ser Tyr Met Asn Ala	
360 365 370	
ACC AAC CAC GCC ATC GTC CAG ACA CTG GTT CAC TTC ATC AAC CCA GAC	1267
Thr Asn His Ala Ile Val Gln Thr Leu Val His Phe Ile Asn Pro Asp	
375 380 385	
ACA GTA CCC AAG CCC TGC TGT GCG CCC ACC CAG CTC AAC GCC ATC TCT	1315
Thr Val Pro Lys Pro Cys Cys Ala Pro Thr Gln Leu Asn Ala Ile Ser	
390 395 400	
GTC CTC TAC TTC GAC GAC AGC TCT AAT GTC ATC CTG AAG AAG TAC AGA	1363
Val Leu Tyr Phe Asp Asp Ser Ser Asn Val Ile Leu Lys Lys Tyr Arg	
405 410 415 420	
AAC ATG GTG GTC CGG GCC TGT GGC TGC CAC TAGCTCTTCC TGAGACCCTG	1413
Asn Met Val Val Arg Ala Cys Gly Cys His	
425 430	
ACCTTTGCGG GGCCACACCT TTCCAAATCT TCGATGTCTC ACCATCTAAG TCTCTCACTG	1473
CCCACCTTGG CGAGGAGAAC AGACCAACCT CTCCTGAGCC TTCCCTCACC TCCCAACCGG	1533
AAGCATGTAA GGGTTCCAGA AACCTGAGCG TGCAGCAGCT GATGAGCGCC CTTTCCTTCT	1593
GGCACGTGAC GGACAAGATC CTACCAGCTA CCACAGCAAA CGCCTAAGAG CAGGAAAAAT	1653

SUBSTITUTE SHEET (RULE 26)

GTCTGCCAGG AAAGTGTCCA GTGTCCACAT GGCCCCCTGGC GCTCTGAGTC TTTGAGGAGT	1713
AATCGCAAGC CTCGTTCAAGC TGCAGCAGAA GGAAGGGCTT AGCCAGGGTG GCGCTGGCG	1773
TCTGTGTTGA AGGGAAACCA AGCAGAAGCC ACTGTAATGA TATGTCACAA TAAACCCAT	1833
GAATGAAAAA AAAAAAAAAA AAAAAAAAAA AAAAGAATTC	1873

(2) INFORMATION FOR SEQ ID NO:18:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 430 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:18:

Met	His	Val	Arg	Ser	Leu	Arg	Ala	Ala	Ala	Pro	His	Ser	Phe	Val	Ala	1	5	10	15
Leu	Trp	Ala	Pro	Leu	Phe	Leu	Leu	Arg	Ser	Ala	Leu	Ala	Asp	Phe	Ser	20	25	30	
Leu	Asp	Asn	Glu	Val	His	Ser	Ser	Phe	Ile	His	Arg	Arg	Leu	Arg	Ser	35	40	45	
Gln	Glu	Arg	Arg	Glu	Met	Gln	Arg	Glu	Ile	Leu	Ser	Ile	Leu	Gly	Leu	50	55	60	
Pro	His	Arg	Pro	Arg	Pro	His	Leu	Gln	Gly	Lys	His	Asn	Ser	Ala	Pro	65	70	75	80
Met	Phe	Met	Leu	Asp	Leu	Tyr	Asn	Ala	Met	Ala	Val	Glu	Glu	Ser	Gly	85	90	95	
Pro	Asp	Gly	Gln	Gly	Phe	Ser	Tyr	Pro	Tyr	Lys	Ala	Val	Phe	Ser	Thr	100	105	110	
Gln	Gly	Pro	Pro	Leu	Ala	Ser	Leu	Gln	Asp	Ser	His	Phe	Leu	Thr	Asp	115	120	125	
Ala	Asp	Met	Val	Met	Ser	Phe	Val	Asn	Leu	Val	Glu	His	Asp	Lys	Glu	130	135	140	
Phe	Phe	His	Pro	Arg	Tyr	His	His	Arg	Glu	Phe	Arg	Phe	Asp	Leu	Ser	145	150	155	160
Lys	Ile	Pro	Glu	Gly	Glu	Arg	Val	Thr	Ala	Ala	Glu	Phe	Arg	Ile	Tyr	165	170	175	
Lys	Asp	Tyr	Ile	Arg	Glu	Arg	Phe	Asp	Asn	Glu	Thr	Phe	Gln	Ile	Thr	180	185	190	
Val	Tyr	Gln	Val	Leu	Gln	Glu	His	Ser	Gly	Arg	Glu	Ser	Asp	Leu	Phe	195	200	205	
Leu	Leu	Asp	Ser	Arg	Thr	Ile	Trp	Ala	Ser	Glu	Glu	Gly	Trp	Leu	Val				

SUBSTITUTE SHEET (RULE 26)

210	215	220
Phe Asp Ile Thr Ala Thr Ser Asn His Trp Val Val Asn Pro Arg His		
225	230	235 240
Asn Leu Gly Leu Gln Leu Ser Val Glu Thr Leu Asp Gly Gln Ser Ile		
	245	250 255
Asn Pro Lys Leu Ala Gly Leu Ile Gly Arg His Gly Pro Gln Asn Lys		
	260	265 270
Gln Pro Phe Met Val Ala Phe Phe Lys Ala Thr Glu Val His Leu Arg		
	275	280 285
Ser Ile Arg Ser Thr Gly Gly Lys Gln Arg Ser Gln Asn Arg Ser Lys		
	290	295 300
Thr Pro Lys Asn Gln Glu Ala Leu Arg Met Ala Ser Val Ala Glu Asn		
	305	310 315 320
Ser Ser Ser Asp Gln Arg Gln Ala Cys Lys Lys His Glu Leu Tyr Val		
	325	330 335
Ser Phe Arg Asp Leu Gly Trp Gln Asp Trp Ile Ile Ala Pro Glu Gly		
	340	345 350
Tyr Ala Ala Tyr Tyr Cys Glu Gly Glu Cys Ala Phe Pro Leu Asn Ser		
	355	360 365
Tyr Met Asn Ala Thr Asn His Ala Ile Val Gln Thr Leu Val His Phe		
	370	375 380
Ile Asn Pro Asp Thr Val Pro Lys Pro Cys Cys Ala Pro Thr Gln Leu		
	385	390 395 400
Asn Ala Ile Ser Val Leu Tyr Phe Asp Asp Ser Ser Asn Val Ile Leu		
	405	410 415
Lys Lys Tyr Arg Asn Met Val Val Arg Ala Cys Gly Cys His		
	420	425 430

(2) INFORMATION FOR SEQ ID NO:19:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1723 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: HOMO SAPIENS
- (F) TISSUE TYPE: HIPPOCAMPUS

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 490..1695
- (D) OTHER INFORMATION: /function= "OSTEOGENIC PROTEIN"

/pr duct= "hOP2-PP"
/n te= "hOP2 (cDNA)"

RECTIFIED SHEET (RULE 91)
ISA/EP

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:19:

GGCGCCGGCA GAGCAGGAGT GGCTGGAGGA GCTGTGGTTG GAGCAGGAGG TGGCACGGCA	60
GGGCTGGAGG GCTCCCTATG AGTGGCGGAG ACGGCCCAGG AGGCGCTGGA GCAACAGCTC	120
CCACACCGCA CCAAGCGGTG GCTGCAGGAG CTCGCCCATC GCCCCTGCGC TGCTCGGACC	180
GCGGCCACAG CCGGACTGGC GGGTACGGCG GCGACAGAGG CATTGGCCGA GAGTCCCAGT	240
CCGCAGAGTA GCCCCGGCCT CGAGGCGGTG GCGTCCCGGT CCTCTCCGTC CAGGAGCCAG	300
GACAGGTGTC GCGCGGCGGG GCTCCAGGGA CCGCGCCTGA GGCCGGCTGC CCGCCCGTCC	360
CGCCCCGCCC CGCCGCCCGC CGCCCGCCGA GCCCAGCCTC CTTGCCGTCG GGGCGTCCCC	420
AGGCCCTGGG TCGGCCGCGG AGCCGATGCG CGCCCGCTGA GCGCCCCAGC TGAGCGCCCC	480
CGGCCTGCC ATG ACC GCG CTC CCC GGC CCG CTC TGG CTC CTG GGC CTG	528
Met Thr Ala Leu Pro Gly Pro Leu Trp Leu Leu Gly Leu	
1 5 10	
GCG CTA TGC GCG CTG GGC GGG GGC GGC CCC GGC CTG CGA CCC CCG CCC	576
Ala Leu Cys Ala Leu Gly Gly Gly Gly Pro Gly Leu Arg Pro Pro Pro	
15 20 25	
GGC TGT CCC CAG CGA CGT CTG GGC GCG CGC GAG CGC CGG GAC GTG CAG	624
Gly Cys Pro Gln Arg Arg Leu Gly Ala Arg Glu Arg Arg Asp Val Gln	
30 35 40 45	
CGC GAG ATC CTG GCG GTG CTC GGG CTG CCT GGG CGG CCC CGG CCC CGC	672
Arg Glu Ile Leu Ala Val Leu Gly Leu Pro Gly Arg Pro Arg Pro Arg	
50 55 60	
GCG CCA CCC GCC GCC TCC CGG CTG CCC GCG TCC GCG CCG CTC TTC ATG	720
Ala Pro Pro Ala Ala Ser Arg Leu Pro Ala Ser Ala Pro Leu Phe Met	
65 70 75	
CTG GAC CTG TAC CAC GCC ATG GCC GGC GAC GAC GAC GAG GAC GGC GCG	768
Leu Asp Leu Tyr His Ala Met Ala Gly Asp Asp Asp Glu Asp Gly Ala	
80 85 90	
CCC GCG GAG CGG CGC CTG GGC CGC GCC GAC CTG GTC ATG AGC TTC GTT	816
Pro Ala Glu Arg Arg Leu Gly Arg Ala Asp Leu Val Met Ser Phe Val	
95 100 105	
AAC ATG GTG GAG CGA GAC CGT GCC CTG GGC CAC CAG GAG CCC CAT TGG	864
Asn Met Val Glu Arg Asp Arg Ala Leu Gly His Gln Glu Pro His Trp	
110 115 120 125	
AAG GAG TTC CGC TTT GAC CTG ACC CAG ATC CCG GCT GGG GAG GCG GTC	912
Lys Glu Phe Arg Phe Asp Leu Thr Gln Ile Pro Ala Gly Glu Ala Val	
130 135 140	
ACA GCT GCG GAG TTC CGG ATT TAC AAG GTG CCC AGC ATC CAC CTG CTC	960
Thr Ala Ala Glu Phe Arg Ile Tyr Lys Val Pro Ser Ile His Leu Leu	
145 150 155	
AAC AGG ACC CTC CAC GTC AGC ATG TTC CAG GTG GTC CAG GAG CAG TCC	1008
Asn Arg Thr Leu His Val Ser Met Phe Gln Val Val Gln Glu Gln Ser	
160 165 170	

SUBSTITUTE SHEET (RULE 26)

AAC	AGG	GAG	TCT	GAC	TTG	TTC	TTT	TTG	GAT	CTT	CAG	ACG	CTC	CGA	GCT	1056
Asn	Arg	Glu	Ser	Asp	Leu	Phe	Phe	Leu	Asp	Leu	Gln	Thr	Leu	Arg	Ala	
	175					180					185					
GGA	GAC	GAG	GGC	TGG	CTG	GTG	CTG	GAT	GTC	ACA	GCA	GCC	AGT	GAC	TGC	1104
Gly	Asp	Glu	Gly	Trp	Leu	Val	Leu	Asp	Val	Thr	Ala	Ala	Ser	Asp	Cys	
190					195					200					205	
TGG	TTG	CTG	AAG	CGT	CAC	AAG	GAC	CTG	GGA	CTC	CGC	CTC	TAT	GTG	GAG	1152
Trp	Leu	Leu	Lys	Arg	His	Lys	Asp	Leu	Gly	Leu	Arg	Leu	Tyr	Val	Glu	
			210						215					220		
ACT	GAG	GAC	GGG	CAC	AGC	GTG	GAT	CCT	GGC	CTG	GCC	GGC	CTG	CTG	GGT	1200
Thr	Glu	Asp		His	Ser	Val	Asp	Pro	Gly	Leu	Ala	Gly	Leu	Leu	Gly	
			225					230					235			
CAA	CGG	GCC	CCA	CGC	TCC	CAA	CAG	CCT	TTC	GTG	GTC	ACT	TTC	TTC	AGG	1248
Gln	Arg	Ala	Pro	Arg	Ser	Gln	Gln	Pro	Phe	Val	Val	Thr	Phe	Phe	Arg	
	240						245					250				
GCC	AGT	CCG	AGT	CCC	ATC	CGC	ACC	CCT	CGG	GCA	GTG	AGG	CCA	CTG	AGG	1296
Ala	Ser	Pro	Ser	Pro	Ile	Arg	Thr	Pro	Arg	Ala	Val	Arg	Pro	Leu	Arg	
	255					260					265					
AGG	AGG	CAG	CCG	AAG	AAA	AGC	AAC	GAG	CTG	CCG	CAG	GCC	AAC	CGA	CTC	1344
Arg	Arg	Gln	Pro	Lys	Lys	Ser	Asn	Glu	Leu	Pro	Gln	Ala	Asn	Arg	Leu	
270					275					280					285	
CCA	GGG	ATC	TTT	GAT	GAC	GTC	CAC	GGC	TCC	CAC	GGC	CGG	CAG	GTC	TGC	1392
Pro	Gly	Ile	Phe	Asp	Asp	Val	His	Gly	Ser	His	Gly	Arg	Gln	Val	Cys	
				290					295					300		
CGT	CGG	CAC	GAG	CTC	TAC	GTC	AGC	TTC	CAG	GAC	CTC	GGC	TGG	CTG	GAC	1440
Arg	Arg	His	Glu	Leu	Tyr	Val	Ser	Phe	Gln	Asp	Leu	Gly	Trp	Leu	Asp	
			305					310					315			
TGG	GTC	ATC	GCT	CCC	CAA	GGC	TAC	TCG	GCC	TAT	TAC	TGT	GAG	GGG	GAG	1488
Trp	Val	Ile	Ala	Pro	Gln	Gly	Tyr	Ser	Ala	Tyr	Tyr	Cys	Glu	Gly	Glu	
	320					325						330				
TGC	TCC	TTC	CCA	CTG	GAC	TCC	TGC	ATG	AAT	GCC	ACC	AAC	CAC	GCC	ATC	1536
Cys	Ser	Phe	Pro	Leu	Asp	Ser	Cys	Met	Asn	Ala	Thr	Asn	His	Ala	Ile	
	335					340					345					
CTG	CAG	TCC	CTG	GTG	CAC	CTG	ATG	AAG	CCA	AAC	GCA	GTC	CCC	AAG	GCG	1584
Leu	Gln	Ser	Leu	Val	His	Leu	Met	Lys	Pro	Asn	Ala	Val	Pro	Lys	Ala	
350					355					360					365	
TGC	TGT	GCA	CCC	ACC	AAG	CTG	AGC	GCC	ACC	TCT	GTG	CTC	TAC	TAT	GAC	1632
Cys	Cys	Ala	Pro	Thr	Lys	Leu	Ser	Ala	Thr	Ser	Val	Leu	Tyr	Tyr	Asp	
				370					375					380		
AGC	AGC	AAC	AAC	GTC	ATC	CTG	CGC	AAA	CAC	CGC	AAC	ATG	GTG	GTC	AAG	1680
Ser	Ser	Asn	Asn	Val	Ile	Leu	Arg	Lys	His	Arg	Asn	Met	Val	Val	Lys	
			385					390					395			
GCC	TGC	GGC	TGC	CAC	TGAGTCAGCC	CGCCCAGCCC	TACTGCAG									1723
Ala	Cys	Gly	Cys	His												
			400													

SUBSTITUTE SHEET (RULE 26)

(2) INFORMATION FOR SEQ ID NO:20:

(i) SEQUENCE CHARACTERISTICS:

(A) LENGTH: 402 amino acids

(B) TYPE: amino acid

(D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:20:

```

Met Thr Ala Leu Pro Gly Pro Leu Trp Leu Leu Gly Leu Ala Leu Cys
 1           5           10           15
Ala Leu Gly Gly Gly Gly Pro Gly Leu Arg Pro Pro Pro Gly Cys Pro
          20           25           30
Gln Arg Arg Leu Gly Ala Arg Glu Arg Arg Asp Val Gln Arg Glu Ile
      35           40           45
Leu Ala Val Leu Gly Leu Pro Gly Arg Pro Arg Pro Arg Ala Pro Pro
 50           55           60
Ala Ala Ser Arg Leu Pro Ala Ser Ala Pro Leu Phe Met Leu Asp Leu
 65           70           75           80
Tyr His Ala Met Ala Gly Asp Asp Asp Glu Asp Gly Ala Pro Ala Glu
          85           90           95
Arg Arg Leu Gly Arg Ala Asp Leu Val Met Ser Phe Val Asn Met Val
      100           105           110
Glu Arg Asp Arg Ala Leu Gly His Gln Glu Pro His Trp Lys Glu Phe
      115           120           125
Arg Phe Asp Leu Thr Gln Ile Pro Ala Gly Glu Ala Val Thr Ala Ala
      130           135           140
Glu Phe Arg Ile Tyr Lys Val Pro Ser Ile His Leu Leu Asn Arg Thr
      145           150           155           160
Leu His Val Ser Met Phe Gln Val Val Gln Glu Gln Ser Asn Arg Glu
          165           170           175
Ser Asp Leu Phe Phe Leu Asp Leu Gln Thr Leu Arg Ala Gly Asp Glu
          180           185           190
Gly Trp Leu Val Leu Asp Val Thr Ala Ala Ser Asp Cys Trp Leu Leu
          195           200           205
Lys Arg His Lys Asp Leu Gly Leu Arg Leu Tyr Val Glu Thr Glu Asp
      210           215           220
Gly His Ser Val Asp Pro Gly Leu Ala Gly Leu Leu Gly Gln Arg Ala
      225           230           235           240
Pro Arg Ser Gln Gln Pro Phe Val Val Thr Phe Phe Arg Ala Ser Pro
          245           250           255
Ser Pro Ile Arg Thr Pro Arg Ala Val Arg Pro Leu Arg Arg Arg Gln
      260           265           270

```

SUBSTITUTE SHEET (RULE 26)

Pro Lys Lys Ser Asn Glu Leu Pro Gln Ala Asn Arg Leu Pro Gly Ile
 275 280 285

Phe Asp Asp Val His Gly Ser His Gly Arg Gln Val Cys Arg Arg His
 290 295 300

Glu Leu Tyr Val Ser Phe Gln Asp Leu Gly Trp Leu Asp Trp Val Ile
 305 310 315 320

Ala Pro Gln Gly Tyr Ser Ala Tyr Tyr Cys Glu Gly Glu Cys Ser Phe
 325 330 335

Pro Leu Asp Ser Cys Met Asn Ala Thr Asn His Ala Ile Leu Gln Ser
 340 345 350

Leu Val His Leu Met Lys Pro Asn Ala Val Pro Lys Ala Cys Cys Ala
 355 360 365

Pro Thr Lys Leu Ser Ala Thr Ser Val Leu Tyr Tyr Asp Ser Ser Asn
 370 375 380

Asn Val Ile Leu Arg Lys His Arg Asn Met Val Val Lys Ala Cys Gly
 385 390 395 400

Cys His

(2) INFORMATION FOR SEQ ID NO:21:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1926 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: MURIDAE
- (F) TISSUE TYPE: EMBRYO

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 93..1289
- (D) OTHER INFORMATION: /function= "OSTEOGENIC PROTEIN"

/product= "mOP2-PP"

/note= "mOP2 cDNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:21:

GCCAGGCACA GGTGCGCCGT CTGGTCCTCC CCGTCTGGCG TCAGCCGAGC CCGACCAGCT 60

ACCA GTGGAT GCGCGCCGGC TGAAAGTCCG AG ATG GCT ATG CGT CCC GGG CCA 113
 Met Ala Met Arg Pro Gly Pro
 1 5

CTC TGG CTA TTG GGC CTT GCT CTG TGC GCG CTG GGA GGC GGC CAC GGT 161
 Leu Trp Leu Leu Gly Leu Ala Leu Cys Ala Leu Gly Gly Gly His Gly
 10 15 20

CCG CGT CCC CCG CAC ACC TGT CCC CAG CGT CGC CTG GGA GCG CGC GAG 209

SUBSTITUTE SHEET (RULE 26)

Pro	Arg	Pro	Pro	His	Thr	Cys	Pro	Gln	Arg	Arg	Leu	Gly	Ala	Arg	Glu		
25						30					35						
CGC	CGC	GAC	ATG	CAG	CGT	GAA	ATC	CTG	GCG	GTG	CTC	GGG	CTA	CCG	GGA	257	
Arg	Arg	Asp	Met	Gln	Arg	Glu	Ile	Leu	Ala	Val	Leu	Gly	Leu	Pro	Gly		
40					45					50					55		
CGG	CCC	CGA	CCC	CGT	GCA	CAA	CCC	GCC	GCT	GCC	CGG	CAG	CCA	GCG	TCC	305	
Arg	Pro	Arg	Pro	Arg	Ala	Gln	Pro	Ala	Ala	Ala	Arg	Gln	Pro	Ala	Ser		
				60				65					70				
GCG	CCC	CTC	TTC	ATG	TTG	GAC	CTA	TAC	CAC	GCC	ATG	ACC	GAT	GAC	GAC	353	
Ala	Pro	Leu	Phe	Met	Leu	Asp	Leu	Tyr	His	Ala	Met	Thr	Asp	Asp	Asp		
			75					80					85				
GAC	GGC	GGG	CCA	CCA	CAG	GCT	CAC	TTA	GGC	CGT	GCC	GAC	CTG	GTC	ATG	401	
Asp	Gly	Gly	Pro	Pro	Gln	Ala	His	Leu	Gly	Arg	Ala	Asp	Leu	Val	Met		
		90					95					100					
AGC	TTC	GTC	AAC	ATG	GTG	GAA	CGC	GAC	CGT	ACC	CTG	GGC	TAC	CAG	GAG	449	
Ser	Phe	Val	Asn	Met	Val	Glu	Arg	Asp	Arg	Thr	Leu	Gly	Tyr	Gln	Glu		
	105					110					115						
CCA	CAC	TGG	AAG	GAA	TTC	CAC	TTT	GAC	CTA	ACC	CAG	ATC	CCT	GCT	GGG	497	
Pro	His	Trp	Lys	Glu	Phe	His	Phe	Asp	Leu	Thr	Gln	Ile	Pro	Ala	Gly		
120					125					130					135		
GAG	GCT	GTC	ACA	GCT	GCT	GAG	TTC	CGG	ATC	TAC	AAA	GAA	CCC	AGC	ACC	545	
Glu	Ala	Val	Thr	Ala	Ala	Glu	Phe	Arg	Ile	Tyr	Lys	Glu	Pro	Ser	Thr		
				140					145					150			
CAC	CCG	CTC	AAC	ACA	ACC	CTC	CAC	ATC	AGC	ATG	TTC	GAA	GTG	GTC	CAA	593	
His	Pro	Leu	Asn	Thr	Thr	Leu	His	Ile	Ser	Met	Phe	Glu	Val	Val	Gln		
			155					160					165				
GAG	CAC	TCC	AAC	AGG	GAG	TCT	GAC	TTG	TTC	TTT	TTG	GAT	CTT	CAG	ACG	641	
Glu	His	Ser	Asn	Arg	Glu	Ser	Asp	Leu	Phe	Phe	Leu	Asp	Leu	Gln	Thr		
		170					175					180					
CTC	CGA	TCT	GGG	GAC	GAG	GGC	TGG	CTG	GTG	CTG	GAC	ATC	ACA	GCA	GCC	689	
Leu	Arg	Ser	Gly	Asp	Glu	Gly	Trp	Leu	Val	Leu	Asp	Ile	Thr	Ala	Ala		
	185					190					195						
AGT	GAC	CGA	TGG	CTG	CTG	AAC	CAT	CAC	AAG	GAC	CTG	GGA	CTC	CGC	CTC	737	
Ser	Asp	Arg	Trp	Leu	Leu	Asn	His	His	Lys	Asp	Leu	Gly	Leu	Arg	Leu		
200					205					210					215		
TAT	GTG	GAA	ACC	GCG	GAT	GGG	CAC	AGC	ATG	GAT	CCT	GGC	CTG	GCT	GGT	785	
Tyr	Val	Glu	Thr	Ala	Asp	Gly	His	Ser	Met	Asp	Pro	Gly	Leu	Ala	Gly		
				220					225					230			
CTG	CTT	GGA	CGA	CAA	GCA	CCA	CGC	TCC	AGA	CAG	CCT	TTC	ATG	GTA	ACC	833	
Leu	Leu	Gly	Arg	Gln	Ala	Pro	Arg	Ser	Arg	Gln	Pro	Phe	Met	Val	Thr		
			235					240					245				
TTC	TTC	AGG	GCC	AGC	CAG	AGT	CCT	GTG	CGG	GCC	CCT	CGG	GCA	GCG	AGA	881	
Phe	Phe	Arg	Ala	Ser	Gln	Ser	Pro	Val	Arg	Ala	Pro	Arg	Ala	Ala	Arg		
		250					255					260					
CCA	CTG	AAG	AGG	AGG	CAG	CCA	AAG	AAA	ACG	AAC	GAG	CTT	CCG	CAC	CCC	929	
Pro	Leu	Lys	Arg	Arg	Gln	Pro	Lys	Lys	Thr	Asn	Glu	Leu	Pro	His	Pro		
	265					270					275						

SUBSTITUTE SHEET (RULE 26)

AAC AAA CTC CCA GGG ATC TTT GAT GAT GGC CAC GGT TCC CGC GGC AGA Asn Lys Leu Pro Gly Ile Phe Asp Asp Gly His Gly Ser Arg Gly Arg 280 285 290 295	977
GAG GTT TGC CGC AGG CAT GAG CTC TAC GTC AGC TTC CGT GAC CTT GGC Glu Val Cys Arg Arg His Glu Leu Tyr Val Ser Phe Arg Asp Leu Gly 300 305 310	1025
TGG CTG GAC TGG GTC ATC GCC CCC CAG GGC TAC TCT GCC TAT TAC TGT Trp Leu Asp Trp Val Ile Ala Pro Gln Gly Tyr Ser Ala Tyr Tyr Cys 315 320 325	1073
GAG GGG GAG TGT GCT TTC CCA CTG GAC TCC TGT ATG AAC GCC ACC AAC Glu Gly Glu Cys Ala Phe Pro Leu Asp Ser Cys Met Asn Ala Thr Asn 330 335 340	1121
CAT GCC ATC TTG CAG TCT CTG GTG CAC CTG ATG AAG CCA GAT GTT GTC His Ala Ile Leu Gln Ser Leu Val His Leu Met Lys Pro Asp Val Val 345 350 355	1169
CCC AAG GCA TGC TGT GCA CCC ACC AAA CTG AGT GCC ACC TCT GTG CTG Pro Lys Ala Cys Cys Ala Pro Thr Lys Leu Ser Ala Thr Ser Val Leu 360 365 370 375	1217
TAC TAT GAC AGC AGC AAC AAT GTC ATC CTG CGT AAA CAC CGT AAC ATG Tyr Tyr Asp Ser Ser Asn Asn Val Ile Leu Arg Lys His Arg Asn Met 380 385 390	1265
GTG GTC AAG GCC TGT GGC TGC CAC TGAGGCCCG CCCAGCATCC TGCTTCTACT Val Val Lys Ala Cys Gly Cys His 395	1319
ACCTTACCAT CTGGCCGGGC CCCTCTCCAG AGGCAGAAAC CCTTCTATGT TATCATAGCT	1379
CAGACAGGGG CAATGGGAGG CCCTTCACTT CCCCTGGCCA CTTCTGCTA AAATTCTGGT	1439
CTTTCCCAGT TCCTCTGTCC TTCATGGGGT TTCGGGGCTA TCACCCCGCC CTCTCCATCC	1499
TCCTACCCCA AGCATAGACT GAATGCACAC AGCATCCCAG AGCTATGCTA ACTGAGAGGT	1559
CTGGGGTCAG CACTGAAGGC CCACATGAGG AAGACTGATC CTTGGCCATC CTCAGCCCAC	1619
AATGGCAAAT TCTGGATGGT CTAAGAAGGC CCTGGAATTC TAACTAGAT GATCTGGGCT	1679
CTCTGCACCA TTCAITGTGG CAGTTGGGAC ATTTTITAGGT ATAACAGACA CATACTTA	1739
GATCAATGCA TCGCTGTACT CCTTGAAATC AGAGCTAGCT TGTTAGAAAA AGAATCAGAG	1799
CCAGGTATAG CGGTGCATGT CATTAAATCCC AGCGCTAAAG AGACAGAGAC AGGAGAATCT	1859
CTGTGAGTTC AAGGCCACAT AGAAAGAGCC TGTCTCGGGA GCAGGAAAAA AAAAAAAAC	1919
GGAATTC	1926

(2) INFORMATION FOR SEQ ID NO:22:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 399 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

SUBSTITUTE SHEET (RULE 26)

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:22:

Met Ala Met Arg Pro Gly Pro Leu Trp Leu Leu Gly Leu Ala Leu Cys
 1 5 10 15
 Ala Leu Gly Gly Gly His Gly Pro Arg Pro Pro His Thr Cys Pro Gln
 20 25 30
 Arg Arg Leu Gly Ala Arg Glu Arg Arg Asp Met Gln Arg Glu Ile Leu
 35 40 45
 Ala Val Leu Gly Leu Pro Gly Arg Pro Arg Pro Arg Ala Gln Pro Ala
 50 55 60
 Ala Ala Arg Gln Pro Ala Ser Ala Pro Leu Phe Met Leu Asp Leu Tyr
 65 70 75 80
 His Ala Met Thr Asp Asp Asp Asp Gly Gly Pro Pro Gln Ala His Leu
 85 90 95
 Gly Arg Ala Asp Leu Val Met Ser Phe Val Asn Met Val Glu Arg Asp
 100 105 110
 Arg Thr Leu Gly Tyr Gln Glu Pro His Trp Lys Glu Phe His Phe Asp
 115 120 125
 Leu Thr Gln Ile Pro Ala Gly Glu Ala Val Thr Ala Ala Glu Phe Arg
 130 135 140
 Ile Tyr Lys Glu Pro Ser Thr His Pro Leu Asn Thr Thr Leu His Ile
 145 150 155 160
 Ser Met Phe Glu Val Val Gln Glu His Ser Asn Arg Glu Ser Asp Leu
 165 170 175
 Phe Phe Leu Asp Leu Gln Thr Leu Arg Ser Gly Asp Glu Gly Trp Leu
 180 185 190
 Val Leu Asp Ile Thr Ala Ala Ser Asp Arg Trp Leu Leu Asn His His
 195 200 205
 Lys Asp Leu Gly Leu Arg Leu Tyr Val Glu Thr Ala Asp Gly His Ser
 210 215 220
 Met Asp Pro Gly Leu Ala Gly Leu Leu Gly Arg Gln Ala Pro Arg Ser
 225 230 235 240
 Arg Gln Pro Phe Met Val Thr Phe Phe Arg Ala Ser Gln Ser Pro Val
 245 250 255
 Arg Ala Pro Arg Ala Ala Arg Pro Leu Lys Arg Arg Gln Pro Lys Lys
 260 265 270
 Thr Asn Glu Leu Pro His Pro Asn Lys Leu Pro Gly Ile Phe Asp Asp
 275 280 285
 Gly His Gly Ser Arg Gly Arg Glu Val Cys Arg Arg His Glu Leu Tyr
 290 295 300
 Val Ser Phe Arg Asp Leu Gly Trp Leu Asp Trp Val Ile Ala Pro Gln

SUBSTITUTE SHEET (RULE 26)

305		310		315		320
Gly Tyr Ser Ala Tyr	Tyr Cys Glu Gly	Glu Cys Ala Phe Pr	Leu Asp			
	325	330	335			
Ser Cys Met Asn Ala Thr	Asn His Ala Ile	Leu Gln Ser Leu	Val His			
	340	345	350			
Leu Met Lys Pro Asp Val	Val Pro Lys Ala Cys	Cys Ala Pro Thr	Lys			
	355	360	365			
Leu Ser Ala Thr Ser Val	Leu Tyr Tyr Asp	Ser Ser Asn Asn	Val Ile			
	370	375	380			
Leu Arg Lys His Arg Asn	Met Val Val Lys	Ala Cys Gly Cys	His			
	385	390	395			

(2) INFORMATION FOR SEQ ID NO:23:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1368 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 1..1365
- (D) OTHER INFORMATION: /label= 60A

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:23:

ATG TCG GGA CTG CGA AAC ACC TCG GAG GCC GTT GCA GTG CTC GCC TCC	48
Met Ser Gly Leu Arg Asn Thr Ser Glu Ala Val Ala Val Leu Ala Ser	
1 5 10 15	
CTG GGA CTC GGA ATG GTT CTG CTC ATG TTC GTG GCG ACC ACG CCG CCG	96
Leu Gly Leu Gly Met Val Leu Leu Met Phe Val Ala Thr Thr Pro Pro	
20 25 30	
GCC GTT GAG GCC ACC CAG TCG GGG ATT TAC ATA GAC AAC GGC AAG GAC	144
Ala Val Glu Ala Thr Gln Ser Gly Ile Tyr Ile Asp Asn Gly Lys Asp	
35 40 45	
CAG ACG ATC ATG CAC AGA GTG CTG AGC GAG GAC GAC AAG CTG GAC GTC	192
Gln Thr Ile Met His Arg Val Leu Ser Glu Asp Asp Lys Leu Asp Val	
50 55 60	
TCG TAC GAG ATC CTC GAG TTC CTG GGC ATC GCC GAA CGG CCG ACG CAC	240
Ser Tyr Glu Ile Leu Glu Phe Leu Gly Ile Ala Glu Arg Pro Thr His	
65 70 75 80	
CTG AGC AGC CAC CAG TTG TCG CTG AGG AAG TCG GCT CCC AAG TTC CTG	288
Leu Ser Ser His Gln Leu Ser Leu Arg Lys Ser Ala Pro Lys Phe Leu	
85 90 95	
CTG GAC GTC TAC CAC CGC ATC ACG GCG GAG GAG GGT CTC AGC GAT CAG	336

RECTIFIED SHEET (RULE 91)
ISA/EP

Leu	Asp	Val	Tyr	His	Arg	Ile	Thr	Ala	Glu	Glu	Gly	Leu	Ser	Asp	Gln		
		100						105						110			
GAT	GAG	GAC	GAC	GAC	TAC	GAA	CGC	GGC	CAT	CGG	TCC	AGG	AGG	AGC	GCC	384	
Asp	Glu	Asp	Asp	Asp	Tyr	Glu	Arg	Gly	His	Arg	Ser	Arg	Arg	Ser	Ala		
		115					120					125					
GAC	CTC	GAG	GAG	GAT	GAG	GGC	GAG	CAG	CAG	AAG	AAC	TTC	ATC	ACC	GAC	432	
Asp	Leu	Glu	Glu	Asp	Glu	Gly	Glu	Gln	Gln	Lys	Asn	Phe	Ile	Thr	Asp		
		130				135					140						
CTG	GAC	AAG	CGG	GCC	ATC	GAC	GAG	AGC	GAC	ATC	ATC	ATG	ACC	TTC	CTG	480	
Leu	Asp	Lys	Arg	Ala	Ile	Asp	Glu	Ser	Asp	Ile	Ile	Met	Thr	Phe	Leu		
145					150					155					160		
AAC	AAG	CGC	CAC	CAC	AAT	GTG	GAC	GAA	CTG	CGT	CAC	GAG	CAC	GGC	CGT	528	
Asn	Lys	Arg	His	His	Asn	Val	Asp	Glu	Leu	Arg	His	Glu	His	Gly	Arg		
			165				170							175			
CGC	CTG	TGG	TTC	GAC	GTC	TCC	AAC	GTG	CCC	AAC	GAC	AAC	TAC	CTG	GTG	576	
Arg	Leu	Trp	Phe	Asp	Val	Ser	Asn	Val	Pro	Asn	Asp	Asn	Tyr	Leu	Val		
			180				185						190				
ATG	GCC	GAG	CTG	CGC	ATC	TAT	CAG	AAC	GCC	AAC	GAG	GGC	AAG	TGG	CTG	624	
Met	Ala	Glu	Leu	Arg	Ile	Tyr	Gln	Asn	Ala	Asn	Glu	Gly	Lys	Trp	Leu		
		195					200					205					
ACC	GCC	AAC	AGG	GAG	TTC	ACC	ATC	ACG	GTA	TAC	GCC	ATT	GGC	ACC	GGC	672	
Thr	Ala	Asn	Arg	Glu	Phe	Thr	Ile	Thr	Val	Tyr	Ala	Ile	Gly	Thr	Gly		
	210					215					220						
ACG	CTG	GGC	CAG	CAC	ACC	ATG	GAG	CCG	CTG	TCC	TCG	GTG	AAC	ACC	ACC	720	
Thr	Leu	Gly	Gln	His	Thr	Met	Glu	Pro	Leu	Ser	Ser	Val	Asn	Thr	Thr		
225					230					235					240		
GGG	GAC	TAC	GTG	GGC	TGG	TTG	GAG	CTC	AAC	GTG	ACC	GAG	GGC	CTG	CAC	768	
Gly	Asp	Tyr	Val	Gly	Trp	Leu	Glu	Leu	Asn	Val	Thr	Glu	Gly	Leu	His		
			245						250					255			
GAG	TGG	CTG	GTC	AAG	TCG	AAG	GAC	AAT	CAT	GGC	ATC	TAC	ATT	GGA	GCA	816	
Glu	Trp	Leu	Val	Lys	Ser	Lys	Asp	Asn	His	Gly	Ile	Tyr	Ile	Gly	Ala		
			260				265						270				
CAC	GCT	GTC	AAC	CGA	CCC	GAC	CGC	GAG	GTG	AAG	CTG	GAC	GAC	ATT	GGA	864	
His	Ala	Val	Asn	Arg	Pro	Asp	Arg	Glu	Val	Lys	Leu	Asp	Asp	Ile	Gly		
		275					280					285					
CTG	ATC	CAC	CGC	AAG	GTG	GAC	GAC	GAG	TTC	CAG	CCC	TTC	ATG	ATC	GGC	912	
Leu	Ile	His	Arg	Lys	Val	Asp	Asp	Glu	Phe	Gln	Pro	Phe	Met	Ile	Gly		
	290					295					300						
TTC	TTC	CGC	GGA	CCG	GAG	CTG	ATC	AAG	GCG	ACG	GCC	CAC	AGC	AGC	CAC	960	
Phe	Phe	Arg	Gly	Pro	Glu	Leu	Ile	Lys	Ala	Thr	Ala	His	Ser	Ser	His		
305					310					315					320		
CAC	AGG	AGC	AAG	CGA	AGC	GCC	AGC	CAT	CCA	CGC	AAG	CGC	AAG	AAG	TCG	1008	
His	Arg	Ser	Lys	Arg	Ser	Ala	Ser	His	Pro	Arg	Lys	Arg	Lys	Lys	Ser		
			325						330					335			
GTG	TCG	CCC	AAC	GTG	CCG	CTG	CTG	GAA	CCG	ATG	GAG	AGC	ACG	CGC		1056	
Val	Ser	Pro	Asn	Val	Pro	Leu	Leu	Glu	Pro	Met	Glu	Ser	Thr	Arg			
			340				345						350				

SUBSTITUTE SHEET (RULE 26)

AGC TGC CAG ATG CAG ACC CTG TAC ATA GAC TTC AAG GAT CTG GGC TGG	1104
Ser Cys Gln Met Gln Thr Leu Tyr Ile Asp Phe Lys Asp Leu Gly Trp	
355 360 365	
CAT GAC TGG ATC ATC GCA CCA GAG GGC TAT GGC GCC TTC TAC TGC AGC	1152
His Asp Trp Ile Ile Ala Pro Glu Gly Tyr Gly Ala Phe Tyr Cys Ser	
370 375 380	
GGC GAG TGC AAT TTC CCG CTC AAT GCG CAC ATG AAC GCC ACG AAC CAT	1200
Gly Glu Cys Asn Phe Pro Leu Asn Ala His Met Asn Ala Thr Asn His	
385 390 395 400	
GCG ATC GTC CAG ACC CTG GTC CAC CTG CTG GAG CCC AAG AAG GTG CCC	1248
Ala Ile Val Gln Thr Leu Val His Leu Leu Glu Pro Lys Lys Val Pro	
405 410 415	
AAG CCC TGC TGC GCT CCG ACC AGG CTG GGA GCA CTA CCC GTT CTG TAC	1296
Lys Pro Cys Cys Ala Pro Thr Arg Leu Gly Ala Leu Pro Val Leu Tyr	
420 425 430	
CAC CTG AAC GAC GAG AAT GTG AAC CTG AAA AAG TAT AGA AAC ATG ATT	1344
His Leu Asn Asp Glu Asn Val Asn Leu Lys Lys Tyr Arg Asn Met Ile	
435 440 445	
GTG AAA TCC TGC GGG TGC CAT TGA	1368
Val Lys Ser Cys Gly Cys His	
450 455	

(2) INFORMATION FOR SEQ ID NO:24:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 455 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:24:

Met Ser Gly Leu Arg Asn Thr Ser Glu Ala Val Ala Val Leu Ala Ser	
1 5 10 15	
Leu Gly Leu Gly Met Val Leu Leu Met Phe Val Ala Thr Thr Pro Pro	
20 25 30	
Ala Val Glu Ala Thr Gln Ser Gly Ile Tyr Ile Asp Asn Gly Lys Asp	
35 40 45	
Gln Thr Ile Met His Arg Val Leu Ser Glu Asp Asp Lys Leu Asp Val	
50 55 60	
Ser Tyr Glu Ile Leu Glu Phe Leu Gly Ile Ala Glu Arg Pro Thr His	
65 70 75 80	
Leu Ser Ser His Gln Leu Ser Leu Arg Lys Ser Ala Pro Lys Phe Leu	
85 90 95	
Leu Asp Val Tyr His Arg Ile Thr Ala Glu Glu Gly Leu Ser Asp Gln	
100 105 110	

SUBSTITUTE SHEET (RULE 26)

Asp Glu Asp Asp Asp Tyr Glu Arg Gly His Arg Ser Arg Arg Ser Ala
 115 120 125
 Asp Leu Glu Glu Asp Glu Gly Glu Gln Gln Lys Asn Phe Ile Thr Asp
 130 135 140
 Leu Asp Lys Arg Ala Ile Asp Glu Ser Asp Ile Ile Met Thr Phe Leu
 145 150 155 160
 Asn Lys Arg His His Asn Val Asp Glu Leu Arg His Glu His Gly Arg
 165 170 175
 Arg Leu Trp Phe Asp Val Ser Asn Val Pro Asn Asp Asn Tyr Leu Val
 180 185 190
 Met Ala Glu Leu Arg Ile Tyr Gln Asn Ala Asn Glu Gly Lys Trp Leu
 195 200 205
 Thr Ala Asn Arg Glu Phe Thr Ile Thr Val Tyr Ala Ile Gly Thr Gly
 210 215 220
 Thr Leu Gly Gln His Thr Met Glu Pro Leu Ser Ser Val Asn Thr Thr
 225 230 235 240
 Gly Asp Tyr Val Gly Trp Leu Glu Leu Asn Val Thr Glu Gly Leu His
 245 250 255
 Glu Trp Leu Val Lys Ser Lys Asp Asn His Gly Ile Tyr Ile Gly Ala
 260 265 270
 His Ala Val Asn Arg Pro Asp Arg Glu Val Lys Leu Asp Asp Ile Gly
 275 280 285
 Leu Ile His Arg Lys Val Asp Asp Glu Phe Gln Pro Phe Met Ile Gly
 290 295 300
 Phe Phe Arg Gly Pro Glu Leu Ile Lys Ala Thr Ala His Ser Ser His
 305 310 315 320
 His Arg Ser Lys Arg Ser Ala Ser His Pro Arg Lys Arg Lys Lys Ser
 325 330 335
 Val Ser Pro Asn Asn Val Pro Leu Leu Glu Pro Met Glu Ser Thr Arg
 340 345 350
 Ser Cys Gln Met Gln Thr Leu Tyr Ile Asp Phe Lys Asp Leu Gly Trp
 355 360 365
 His Asp Trp Ile Ile Ala Pro Glu Gly Tyr Gly Ala Phe Tyr Cys Ser
 370 375 380
 Gly Glu Cys Asn Phe Pro Leu Asn Ala His Met Asn Ala Thr Asn His
 385 390 395 400
 Ala Ile Val Gln Thr Leu Val His Leu Leu Glu Pro Lys Lys Val Pro
 405 410 415
 Lys Pro Cys Cys Ala Pro Thr Arg Leu Gly Ala Leu Pro Val Leu Tyr
 420 425 430
 His Leu Asn Asp Glu Asn Val Asn Leu Lys Lys Tyr Arg Asn Met Ile
 435 440 445

SUBSTITUTE SHEET (RULE 26)

Val Lys Ser Cys Gly Cys His
450 455

(2) INFORMATION FOR SEQ ID NO:25:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1674 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ix) FEATURE:

- (A) NAME/KEY: CDS
- (B) LOCATION: 69..1265
- (D) OTHER INFORMATION: /note= "mOP3-PP"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:25:

GGATCCGCGG CGCTGTCCCA TCCTTGTCGT CGAGGCGTCG CTGGATGCGA GTCCGCTAAA	60
CGTCCGAG ATG GCT GCG CGT CCG GGA CTC CTA TGG CTA CTG GGC CTG GCT	110
Met Ala Ala Arg Pro Gly Leu Leu Trp Leu Leu Gly Leu Ala	
1 5 10	
CTG TGC GTG TTG GGC GGC GGT CAC CTC TCG CAT CCC CCG CAC GTC TTT	158
Leu Cys Val Leu Gly Gly Gly His Leu Ser His Pro Pro His Val Phe	
15 20 25 30	
CCC CAG CGT CGA CTA GGA GTA CGC GAG CCC CGC GAC ATG CAG CGC GAG	206
Pro Gln Arg Arg Leu Gly Val Arg Glu Pro Arg Asp Met Gln Arg Glu	
35 40 45	
ATT CGG GAG GTG CTG GGG CTA GCC GGG CGG CCC CGA TCC CGA GCA CCG	254
Ile Arg Glu Val Leu Gly Leu Ala Gly Arg Pro Arg Ser Arg Ala Pro	
50 55 60	
GTC GGG GCT GCC CAG CAG CCA GCG TCT GCG CCC CTC TTT ATG TTG GAC	302
Val Gly Ala Ala Gln Gln Pro Ala Ser Ala Pro Leu Phe Met Leu Asp	
65 70 75	
CTG TAC CGT GCC ATG ACG GAT GAC AGT GGC GGT GGG ACC CCG CAG CCT	350
Leu Tyr Arg Ala Met Thr Asp Asp Ser Gly Gly Gly Thr Pro Gln Pro	
80 85 90	
CAC TTG GAC CGT GCT GAC CTG ATT ATG AGC TTT GTC AAC ATA GTG GAA	398
His Leu Asp Arg Ala Asp Leu Ile Met Ser Phe Val Asn Ile Val Glu	
95 100 105 110	
CGC GAC CGT ACC CTG GGC TAC CAG GAG CCA CAC TGG AAG GAA TTC CAC	446
Arg Asp Arg Thr Leu Gly Tyr Gln Glu Pro His Trp Lys Glu Phe His	
115 120 125	
TTT GAC CTA ACC CAG ATC CCT GCT GGG GAG GCT GTC ACA GCT GCT GAG	494
Phe Asp Leu Thr Gln Ile Pro Ala Gly Glu Ala Val Thr Ala Ala Glu	
130 135 140	
TTC CGG ATC TAC AAA GAA CCC AGT ACC CAC CCG CTC AAC ACA ACC CTC	542
Phe Arg Ile Tyr Lys Glu Pr Ser Thr His Pro Leu Asn Thr Thr Leu	

RECTIFIED SHEET (RULE 91)
ISA/EP

145	150	155	
CAC ATC AGC ATG TTC GAA GTG GTC CAA GAG CAC TCC AAC AGG GAG TCT			590
His Ile Ser Met Phe Glu Val Val Gln Glu His Ser Asn Arg Glu Ser			
160	165	170	
GAC TTG TTC TTT TTG GAT CTT CAG ACG CTC CGA TCT GGG GAC GAG GGC			638
Asp Leu Phe Phe Leu Asp Leu Gln Thr Leu Arg Ser Gly Asp Glu Gly			
175	180	185	190
TGG CTG GTG CTG GAC ATC ACA GCA GCC AGT GAC CGA TGG CTG CTG AAC			686
Trp Leu Val Leu Asp Ile Thr Ala Ala Ser Asp Arg Trp Leu Leu Asn			
195	200	205	
CAT CAC AAG GAC CTA GGA CTC CGC CTC TAT GTG GAA ACC GAG GAT GGC			734
His His Lys Asp Leu Gly Leu Arg Leu Tyr Val Glu Thr Glu Asp Gly			
210	215	220	
CAC AGC ATA GAT CCT GGC CTA GCT GGT CTG CTT GGA CGA CAA GCA CCA			782
His Ser Ile Asp Pro Gly Leu Ala Gly Leu Leu Gly Arg Gln Ala Pro			
225	230	235	
CGC TCC AGA CAG CCT TTC ATG GTT GGT TTC TTC AGG GCC AAC CAG AGT			830
Arg Ser Arg Gln Pro Phe Met Val Gly Phe Phe Arg Ala Asn Gln Ser			
240	245	250	
CCT GTG CGG GCC CCT CGA ACA GCA AGA CCA CTG AAG AAG AAG CAG CTA			878
Pro Val Arg Ala Pro Arg Thr Ala Arg Pro Leu Lys Lys Lys Gln Leu			
255	260	265	270
AAT CAA ATC AAC CAG CTG CCG CAC TCC AAC AAA CAC CTA GGA ATC CTT			926
Asn Gln Ile Asn Gln Leu Pro His Ser Asn Lys His Leu Gly Ile Leu			
275	280	285	
GAT GAT GGC CAC GGT TCT CAC GGC AGA GAA GTT TGC CGC AGG CAT GAG			974
Asp Asp Gly His Gly Ser His Gly Arg Glu Val Cys Arg Arg His Glu			
290	295	300	
CTC TAT GTC AGC TTC CGT GAC CTT GGC TGG CTG GAC TCT GTC ATT GCC			1022
Leu Tyr Val Ser Phe Arg Asp Leu Gly Trp Leu Asp Ser Val Ile Ala			
305	310	315	
CCC CAG GGC TAC TCC GCC TAT TAC TGT GCT GGG GAG TGC ATC TAC CCA			1070
Pro Gln Gly Tyr Ser Ala Tyr Cys Ala Gly Glu Cys Ile Tyr Pro			
320	325	330	
CTG AAC TCC TGT ATG AAC TCC ACC AAC CAC GCC ACT ATG CAG GCC CTG			1118
Leu Asn Ser Cys Met Asn Ser Thr Asn His Ala Thr Met Gln Ala Leu			
335	340	345	350
GTA CAT CTG ATG AAG CCA GAT ATC ATC CCC AAG GTG TGC TGT GTG CCT			1166
Val His Leu Met Lys Pro Asp Ile Ile Pro Lys Val Cys Cys Val Pro			
355	360	365	
ACT GAG CTG AGT GCC ATT TCT CTG CTC TAC TAT GAT AGA AAC AAT AAT			1214
Thr Glu Leu Ser Ala Ile Ser Leu Leu Tyr Tyr Asp Arg Asn Asn Asn			
370	375	380	
GTC ATC CTG CGC AGG GAG CGC AAC ATG GTA GTC CAG GCC TGT GGC TGC			1262
Val Ile Leu Arg Arg Glu Arg Asn Met Val Val Gln Ala Cys Gly Cys			
385	390	395	
CAC TGAGTCCCTG CCCAACAGCC TGCTGCCATC CCATCTATCT AGTCAGGCCT			1315

SUBSTITUTE SHEET (RULE 26)

His

CTCTTCCAAG GCAGGAAACC AACAAAGAGG GAAGGCAGTG CTTTCAACTC CATGTCCACA 1375
 TTCACAGTCT TGGCCCTCTC TGTTCTTTTT GCCAAGGCTG AGAAGATGGT CCTAGTTATA 1435
 ACCCTGGTGA CCTCAGTAGC CCGATCTCTC ATCTCCCCAA ACTCCCCAAT GCAGCCAGGG 1495
 GCATCTATGT CCTTTGGGAT TGGGCACAGA AGTCCAATTT ACCAACTTAT TCATGAGTCA 1555
 CTA CTGGCCC AGCCTGGACT TGAACCTGGA ACACAGGGTA GAGCTCAGGC TCTTCAGTAT 1615
 CCATCAGAAG ATTTAGGTGT GTGCAGACAT GACCACACTC CCCCTAGCAC TCCATAGCC 1674

(2) INFORMATION FOR SEQ ID NO:26:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 399 amino acids
 (B) TYPE: amino acid
 (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:26:

Met Ala Ala Arg Pro Gly Leu Leu Trp Leu Leu Gly Leu Ala Leu Cys
 1 5 10 15
 Val Leu Gly Gly Gly His Leu Ser His Pro Pro His Val Phe Pro Gln
 20 25 30
 Arg Arg Leu Gly Val Arg Glu Pro Arg Asp Met Gln Arg Glu Ile Arg
 35 40 45
 Glu Val Leu Gly Leu Ala Gly Arg Pro Arg Ser Arg Ala Pro Val Gly
 50 55 60
 Ala Ala Gln Gln Pro Ala Ser Ala Pro Leu Phe Met Leu Asp Leu Tyr
 65 70 75 80
 Arg Ala Met Thr Asp Asp Ser Gly Gly Gly Thr Pro Gln Pro His Leu
 85 90 95
 Asp Arg Ala Asp Leu Ile Met Ser Phe Val Asn Ile Val Glu Arg Asp
 100 105 110
 Arg Thr Leu Gly Tyr Gln Glu Pro His Trp Lys Glu Phe His Phe Asp
 115 120 125
 Leu Thr Gln Ile Pro Ala Gly Glu Ala Val Thr Ala Ala Glu Phe Arg
 130 135 140
 Ile Tyr Lys Glu Pro Ser Thr His Pro Leu Asn Thr Thr Leu His Ile
 145 150 155 160
 Ser Met Phe Glu Val Val Gln Glu His Ser Asn Arg Glu Ser Asp Leu
 165 170 175
 Phe Phe Leu Asp Leu Gln Thr Leu Arg Ser Gly Asp Glu Gly Trp Leu

SUBSTITUTE SHEET (RULE 26)

180	185	190
Val Leu Asp Ile Thr Ala Ala Ser Asp Arg Trp Leu Leu Asn His His		
195	200	205
Lys Asp Leu Gly Leu Arg Leu Tyr Val Glu Thr Glu Asp Gly His Ser		
210	215	220
Ile Asp Pro Gly Leu Ala Gly Leu Leu Gly Arg Gln Ala Pro Arg Ser		
225	230	235
Arg Gln Pro Phe Met Val Gly Phe Phe Arg Ala Asn Gln Ser Pro Val		
245	250	255
Arg Ala Pro Arg Thr Ala Arg Pro Leu Lys Lys Lys Gln Leu Asn Gln		
260	265	270
Ile Asn Gln Leu Pro His Ser Asn Lys His Leu Gly Ile Leu Asp Asp		
275	280	285
Gly His Gly Ser His Gly Arg Glu Val Cys Arg Arg His Glu Leu Tyr		
290	295	300
Val Ser Phe Arg Asp Leu Gly Trp Leu Asp Ser Val Ile Ala Pro Gln		
305	310	315
Gly Tyr Ser Ala Tyr Tyr Cys Ala Gly Glu Cys Ile Tyr Pro Leu Asn		
325	330	335
Ser Cys Met Asn Ser Thr Asn His Ala Thr Met Gln Ala Leu Val His		
340	345	350
Leu Met Lys Pro Asp Ile Ile Pro Lys Val Cys Cys Val Pro Thr Glu		
355	360	365
Leu Ser Ala Ile Ser Leu Leu Tyr Tyr Asp Arg Asn Asn Asn Val Ile		
370	375	380
Leu Arg Arg Glu Arg Asn Met Val Val Gln Ala Cys Gly Cys His		
385	390	395

(2) INFORMATION FOR SEQ ID NO:27:

- (i) SEQUENCE CHARACTERISTICS:
- (A) LENGTH: 104 amino acids
 - (B) TYPE: amino acid
 - (C) STRANDEDNESS:
 - (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(ix) FEATURE:

- (A) NAME/KEY: Protein
- (B) LOCATION: 1..104
- (D) OTHER INFORMATION: /note= "BMP3"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:27:

Cys Ala Arg Arg Tyr Leu Lys Val Asp Phe Ala Asp Ile Gly Trp Ser

SUBSTITUTE SHEET (RULE 26)

```

1           5           10           15
Glu Trp Ile Ile Ser Pro Lys Ser Phe Asp Ala Tyr Tyr Cys Ser Gly
                20                25                30
Ala Cys Gln Phe Pro Met Pro Lys Ser Leu Lys Pro Ser Asn His Ala
                35                40                45
Thr Ile Gln Ser Ile Val Ala Arg Ala Val Gly Val Val Pro Gly Ile
                50                55                60
Pro Glu Pro Cys Cys Val Pro Glu Lys Met Ser Ser Leu Ser Ile Leu
        65                70                75                80
Phe Phe Asp Glu Asn Lys Asn Val Val Leu Lys Val Tyr Pro Asn Met
                85                90                95
Thr Val Glu Ser Cys Ala Cys Arg
                100

```

(2) INFORMATION FOR SEQ ID NO:28:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 102 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: HOMO SAPIENS

(ix) FEATURE:

- (A) NAME/KEY: Protein
- (B) LOCATION: 1..102
- (D) OTHER INFORMATION: /note= "BMP5"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:28:

```

Cys Lys Lys His Glu Leu Tyr Val Ser Phe Arg Asp Leu Gly Trp Gln
1           5           10           15
Asp Trp Ile Ile Ala Pro Glu Gly Tyr Ala Ala Phe Tyr Cys Asp Gly
                20                25                30
Glu Cys Ser Phe Pro Leu Asn Ala His Met Asn Ala Thr Asn His Ala
                35                40                45
Ile Val Gln Thr Leu Val His Leu Met Phe Pro Asp His Val Pro Lys
                50                55                60
Pro Cys Cys Ala Pro Thr Lys Leu Asn Ala Ile Ser Val Leu Tyr Phe
        65                70                75                80
Asp Asp Ser Ser Asn Val Ile Leu Lys Lys Tyr Arg Asn Met Val Val
                85                90                95
Arg Ser Cys Gly Cys His
                100

```

SUBSTITUTE SHEET (RULE 26)

(2) INFORMATION FOR SEQ ID NO:29:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 102 amino acids
- (B) TYPE: amino acid
- (C) STRANDEDNESS:
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: HOMO SAPIENS

(ix) FEATURE:

- (A) NAME/KEY: Protein
- (B) LOCATION: 1..102
- (D) OTHER INFORMATION: /note= "BMP6"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:29:

```

Cys Arg Lys His Glu Leu Tyr Val Ser Phe Gln Asp Leu Gly Trp Gln
1           5              10              15
Asp Trp Ile Ile Ala Pro Lys Gly Tyr Ala Ala Asn Tyr Cys Asp Gly
          20              25              30
Glu Cys Ser Phe Pro Leu Asn Ala His Met Asn Ala Thr Asn His Ala
          35              40              45
Ile Val Gln Thr Leu Val His Leu Met Asn Pro Glu Tyr Val Pro Lys
          50              55              60
Pro Cys Cys Ala Pro Thr Lys Leu Asn Ala Ile Ser Val Leu Tyr Phe
          65              70              75              80
Asp Asp Asn Ser Asn Val Ile Leu Lys Lys Tyr Arg Trp Met Val Val
          85              90              95
Arg Ala Cys Gly Cys His
          100

```

(2) INFORMATION FOR SEQ ID NO:30:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 1247 base pairs
- (B) TYPE: nucleic acid
- (C) STRANDEDNESS: single
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: cDNA

(vi) ORIGINAL SOURCE:

- (A) ORGANISM: HOMO SAPIENS
- (F) TISSUE TYPE: BRAIN

(ix) FEATURE:

- (A) NAME/KEY: CDS

SUBSTITUTE SHEET (RULE 26)

(B) LOCATION: 84..1199

(D) OTHER INFORMATION: /product= "GDF-1"

/note= "GDF-1 CDNA"

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:30:

GGGGACACCG GCCCCGCCCT CAGCCCCTG GTCCCGGGCC GCCGCGGACC CTGCGCACTC	60
TCTGGTCATC GCCTGGGAGG AAG ATG CCA CCG CCG CAG CAA GGT CCC TGC	110
Met Pro Pro Pro Gln Gln Gly Pro Cys	
1 5	
GGC CAC CAC CTC CTC CTC CTC CTG GCC CTG CTG CTG CCC TCG CTG CCC	158
Gly His His Leu Leu Leu Leu Leu Ala Leu Leu Leu Pro Ser Leu Pro	
10 15 20 25	
CTG ACC CGC GCC CCC GTG CCC CCA GGC CCA GCC GCC GCC CTG CTC CAG	206
Leu Thr Arg Ala Pro Val Pro Pro Gly Pro Ala Ala Ala Leu Leu Gln	
30 35 40	
GCT CTA GGA CTG CGC GAT GAG CCC CAG GGT GCC CCC AGG CTC CGG CCG	254
Ala Leu Gly Leu Arg Asp Glu Pro Gln Gly Ala Pro Arg Leu Arg Pro	
45 50 55	
GTT CCC CCG GTC ATG TGG CGC CTG TTT CGA CGC CGG GAC CCC CAG GAG	302
Val Pro Pro Val Met Trp Arg Leu Phe Arg Arg Arg Asp Pro Gln Glu	
60 65 70	
ACC AGG TCT GGC TCG CGG CGG ACG TCC CCA GGG GTC ACC CTG CAA CCG	350
Thr Arg Ser Gly Ser Arg Arg Thr Ser Pro Gly Val Thr Leu Gln Pro	
75 80 85	
TGC CAC GTG GAG GAG CTG GGG GTC GCC GGA AAC ATC GTG CGC CAC ATC	398
Cys His Val Glu Glu Leu Gly Val Ala Gly Asn Ile Val Arg His Ile	
90 95 100 105	
CCG GAC CGC GGT GCG CCC ACC CGG GCC TCG GAG CCT GTC TCG GCC GCG	446
Pro Asp Arg Gly Ala Pro Thr Arg Ala Ser Glu Pro Val Ser Ala Ala	
110 115 120	
GGG CAT TGC CCT GAG TGG ACA GTC GTC TTC GAC CTG TCG GCT GTG GAA	494
Gly His Cys Pro Glu Trp Thr Val Val Phe Asp Leu Ser Ala Val Glu	
125 130 135	
CCC GCT GAG CGC CCG AGC CGG GCC CGC CTG GAG CTG CGT TTC GCG GCG	542
Pro Ala Glu Arg Pro Ser Arg Ala Arg Leu Glu Leu Arg Phe Ala Ala	
140 145 150	
GCG GCG GCG GCA GCC CCG GAG GGC GGC TGG GAG CTG AGC GTG GCG CAA	590
Ala Ala Ala Ala Ala Pro Glu Gly Gly Trp Glu Leu Ser Val Ala Gln	
155 160 165	
GCG GGC CAG GGC GCG GGC GCG GAC CCC GGG CCG GTG CTG CTC CGC CAG	638
Ala Gly Gln Gly Ala Glu Ala Asp Pro Gly Pro Val Leu Leu Arg Gln	
170 175 180 185	
TTG GTG CCC GCC CTG GGG CCG CCA GTG CGC GCG GAG CTG CTG GGC GCC	686
Leu Val Pro Ala Leu Gly Pro Pro Val Arg Ala Glu Leu Leu Gly Ala	
190 195 200	
GCT TGG GCT CGC AAC GCC TCA TGG CCG CGC AGC CTC CGC CTG GCG CTG	734
Ala Trp Ala Arg Asn Ala Ser Trp Pro Arg Ser Leu Arg Leu Ala Leu	

SUBSTITUTE SHEET (RULE 26)

205						210						215						
GCG	CTA	CGC	CCC	CGG	GCC	CCT	GCC	GCC	TGC	GCG	CGC	CTG	GCC	GAG	GCC	782		
Ala	Leu	Arg	Pro	Arg	Ala	Pro	Ala	Ala	Cys	Ala	Arg	Leu	Ala	Glu	Ala			
		220					225					230						
TCG	CTG	CTG	CTG	GTG	ACC	CTC	GAC	CCG	CGC	CTG	TGC	CAC	CCC	CTG	GCC	830		
Ser	Leu	Leu	Leu	Val	Thr	Leu	Asp	Pro	Arg	Leu	Cys	His	Pro	Leu	Ala			
		235				240					245							
CGG	CCG	CGG	CGC	GAC	GCC	GAA	CCC	GTG	TTG	GGC	GGC	GGC	CCC	GGG	GGC	878		
Arg	Pro	Arg	Arg	Asp	Ala	Glu	Pro	Val	Leu	Gly	Gly	Gly	Pro	Gly	Gly			
250				255						260				265				
GCT	TGT	CGC	GCG	CGG	CGG	CTG	TAC	GTG	AGC	TTC	CGC	GAG	GTG	GGC	TGG	926		
Ala	Cys	Arg	Ala	Arg	Arg	Leu	Tyr	Val	Ser	Phe	Arg	Glu	Val	Gly	Trp			
				270					275					280				
CAC	CGC	TGG	GTC	ATC	GCG	CCG	CGC	GGC	TTC	CTG	GCC	AAC	TAC	TGC	CAG	974		
His	Arg	Trp	Val	Ile	Ala	Pro	Arg	Gly	Phe	Leu	Ala	Asn	Tyr	Cys	Gln			
			285					290					295					
GGT	CAG	TGC	GCG	CTG	CCC	GTC	GCG	CTG	TCG	GGG	TCC	GGG	GGG	CCG	CCG	1022		
Gly	Gln	Cys	Ala	Leu	Pro	Val	Ala	Leu	Ser	Gly	Ser	Gly	Gly	Pro	Pro			
		300					305					310						
GCG	CTC	AAC	CAC	GCT	GTG	CTG	CGC	GCG	CTC	ATG	CAC	GCG	GCC	GCC	CCG	1070		
Ala	Leu	Asn	His	Ala	Val	Leu	Arg	Ala	Leu	Met	His	Ala	Ala	Ala	Pro			
		315				320					325							
GGA	GCC	GCC	GAC	CTG	CCC	TGC	TGC	GTG	CCC	GCG	CGC	CTG	TCG	CCC	ATC	1118		
Gly	Ala	Ala	Asp	Leu	Pro	Cys	Cys	Val	Pro	Ala	Arg	Leu	Ser	Pro	Ile			
330					335					340					345			
TCC	GTG	CTC	TTC	TTT	GAC	AAC	AGC	GAC	AAC	GTG	GTG	CTG	CGG	CAG	TAT	1166		
Ser	Val	Leu	Phe	Phe	Asp	Asn	Ser	Asp	Asn	Val	Val	Leu	Arg	Gln	Tyr			
				350					355					360				
GAG	GAC	ATG	GTG	GTG	GAC	GAG	TGC	GGC	TGC	CGC	TAACCCGGGG	CGGGCAGGGA				1219		
Glu	Asp	Met	Val	Val	Asp	Glu	Cys	Gly	Cys	Arg								
			365					370										
CCCGGGCCCA ACAATAAATG CCGCGTGG																1247		

(2) INFORMATION FOR SEQ ID NO:31:

(i) SEQUENCE CHARACTERISTICS:

- (A) LENGTH: 372 amino acids
- (B) TYPE: amino acid
- (D) TOPOLOGY: linear

(ii) MOLECULE TYPE: protein

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:31:

Met Pro Pro Pro Gln Gln Gly Pro Cys Gly His His Leu Leu Leu Leu
1 5 10 15

Leu Ala Leu Leu Leu Pro Ser Leu Pro Leu Thr Arg Ala Pro Val Pro
20 25 30

SUBSTITUTE SHEET (RULE 26)

Pro Gly Pro Ala Ala Ala Leu Leu Gln Ala Leu Gly Leu Arg Asp Glu
 35 40 45
 Pro Gln Gly Ala Pro Arg Leu Arg Pro Val Pro Pro Val Met Trp Arg
 50 55 60
 Leu Phe Arg Arg Arg Asp Pro Gln Glu Thr Arg Ser Gly Ser Arg Arg
 65 70 75 80
 Thr Ser Pro Gly Val Thr Leu Gln Pro Cys His Val Glu Glu Leu Gly
 85 90 95
 Val Ala Gly Asn Ile Val Arg His Ile Pro Asp Arg Gly Ala Pro Thr
 100 105 110
 Arg Ala Ser Glu Pro Val Ser Ala Ala Gly His Cys Pro Glu Trp Thr
 115 120 125
 Val Val Phe Asp Leu Ser Ala Val Glu Pro Ala Glu Arg Pro Ser Arg
 130 135 140
 Ala Arg Leu Glu Leu Arg Phe Ala Ala Ala Ala Ala Ala Pro Glu
 145 150 155 160
 Gly Gly Trp Glu Leu Ser Val Ala Gln Ala Gly Gln Gly Ala Gly Ala
 165 170 175
 Asp Pro Gly Pro Val Leu Leu Arg Gln Leu Val Pro Ala Leu Gly Pro
 180 185 190
 Pro Val Arg Ala Glu Leu Leu Gly Ala Ala Trp Ala Arg Asn Ala Ser
 195 200 205
 Trp Pro Arg Ser Leu Arg Leu Ala Leu Ala Leu Arg Pro Arg Ala Pro
 210 215 220
 Ala Ala Cys Ala Arg Leu Ala Glu Ala Ser Leu Leu Leu Val Thr Leu
 225 230 235 240
 Asp Pro Arg Leu Cys His Pro Leu Ala Arg Pro Arg Arg Asp Ala Glu
 245 250 255
 Pro Val Leu Gly Gly Gly Pro Gly Gly Ala Cys Arg Ala Arg Arg Leu
 260 265 270
 Tyr Val Ser Phe Arg Glu Val Gly Trp His Arg Trp Val Ile Ala Pro
 275 280 285
 Arg Gly Phe Leu Ala Asn Tyr Cys Gln Gly Gln Cys Ala Leu Pro Val
 290 295 300
 Ala Leu Ser Gly Ser Gly Gly Pro Pro Ala Leu Asn His Ala Val Leu
 305 310 315 320
 Arg Ala Leu Met His Ala Ala Ala Pro Gly Ala Ala Asp Leu Pro Cys
 325 330 335
 Cys Val Pro Ala Arg Leu Ser Pro Ile Ser Val Leu Phe Phe Asp Asn
 340 345 350
 Ser Asp Asn Val Val Leu Arg Gln Tyr Glu Asp Met Val Val Asp Glu
 355 360 365

SUBSTITUTE SHEET (RULE 26)

Cys Gly Cys Arg
370

(2) INFORMATION FOR SEQ ID NO:32:

- (i) SEQUENCE CHARACTERISTICS:
 (A) LENGTH: 4 amino acids
 (B) TYPE: amino acid
 (C) STRANDEDNESS:
 (D) TOPOLOGY: linear

(xi) SEQUENCE DESCRIPTION: SEQ ID NO:32:

Arg Xaa Xaa Arg
1

- 79 -

What is claimed is:

- 1 1. A method for stimulating morphogenesis of dentine in a mammalian tooth, comprising the
2 step of applying a morphogen to a dentinal surface of said tooth.
- 1 2. A method for stimulating phenotypic expression of mammalian odontoblasts, comprising
2 the step of applying a morphogen to a dentinal surface of a mammalian tooth.
- 1 3. A method for stimulating production of dentine matrix by mammalian odontoblasts,
2 comprising the step of applying a morphogen to a dentinal surface of a mammalian tooth.
- 1 4. A method for increasing thickness of a mammalian tooth wall, comprising the step of
2 applying a morphogen to a dentinal surface of said tooth.
- 1 5. A method for reducing risk of fracture in a mammalian tooth, comprising the step of
2 applying a morphogen to a dentinal surface of said tooth.
- 1 6. The method of claim 1, 2, 3, 4 or 5 wherein said surface adjoins a site of lost or damaged
2 enamel, dentine or cementum tissue in said tooth.
- 1 7. The method of claim 6 wherein said surface adjoins a cavity in said tooth.
- 1 8. The method of claim 7, further comprising the preparative step of ablating damaged or
2 infected enamel, dentine or cementum tissue from the site of said cavity.
- 1 9. A method for sealing a cavity in a mammalian tooth, comprising the step of applying a
2 morphogen to a dentinal surface within said cavity.
- 1 10. The method of claim 9, further comprising the preparative step of ablating damaged or
2 infected enamel, dentine or cementum tissue from the site of said cavity.
- 1 11. A method for desensitizing a mammalian tooth to perception of pressure or temperature,
2 comprising the step of applying a morphogen to a dentinal surface of said tooth.
- 1 12. The method of claim 1, 2, 3, 4, 5 or 11 wherein said surface adjoins a site of lost or
2 damaged gingival tissue .

- 80 -

- 1 13. The method of claim 12, further comprising the preparative step of debriding damaged
2 gingival, enamel, dentine or cementum tissue from said surface.
- 1 14. The method of claim 1, 2, 3, 4, 5, 9 or 11 wherein said morphogen is applied in an amount
2 effective for stimulating formation of reparative dentine apposite said surface.
- 1 15. The method of claim 14 wherein said surface is transverse to luminae of dental canaliculi
2 within said tooth.
- 1 16. The method of claim 1, 2, 3, 4, 5, 9 or 11 wherein said surface is separated from the pulp
2 chamber wall of said tooth by up to about 1 mm of residual dentine.
- 1 17. The method of claim 16 wherein said surface is separated from the pulp chamber wall of
2 said tooth by up to about 0.5 mm of residual dentin.
- 1 18. The method of claim 17 wherein said surface is separated from the pulp chamber wall of
2 said tooth by up to about 0.2 mm of residual dentin.
- 1 19. The method of claim 1, 2, 3, 4, 5, 9 or 11, further comprising the preparative step of
2 solubilizing said morphogen in a physiologically acceptable vehicle or an evaporative
3 vehicle.
- 1 20. The method of claim 1, 2, 3, 4, 5, 9 or 11 wherein said morphogen is solubilized in a
2 physiologically acceptable vehicle or an evaporative vehicle.
- 1 21. The method of claim 20 wherein said vehicle further comprises a cofactor that mitigates
2 symptoms associated with tooth damage.
- 1 22. The method of claim 1, 2, 3, 4, 5, 9 or 11, further comprising the preparative step of
2 adsorbing said morphogen on a biocompatible, acellular matrix suitable for sealing or
3 filling defects in mammalian teeth.
- 1 23. The method of claim 1, 2, 3, 4, 5, 9 or 11 wherein said morphogen is adsorbed on a
2 biocompatible, acellular matrix suitable for sealing or filling defects in mammalian teeth.
- 1 24. The method of claim 23 wherein said matrix further comprises a cofactor that mitigates
2 symptoms associated with tooth damage.

- 81 -

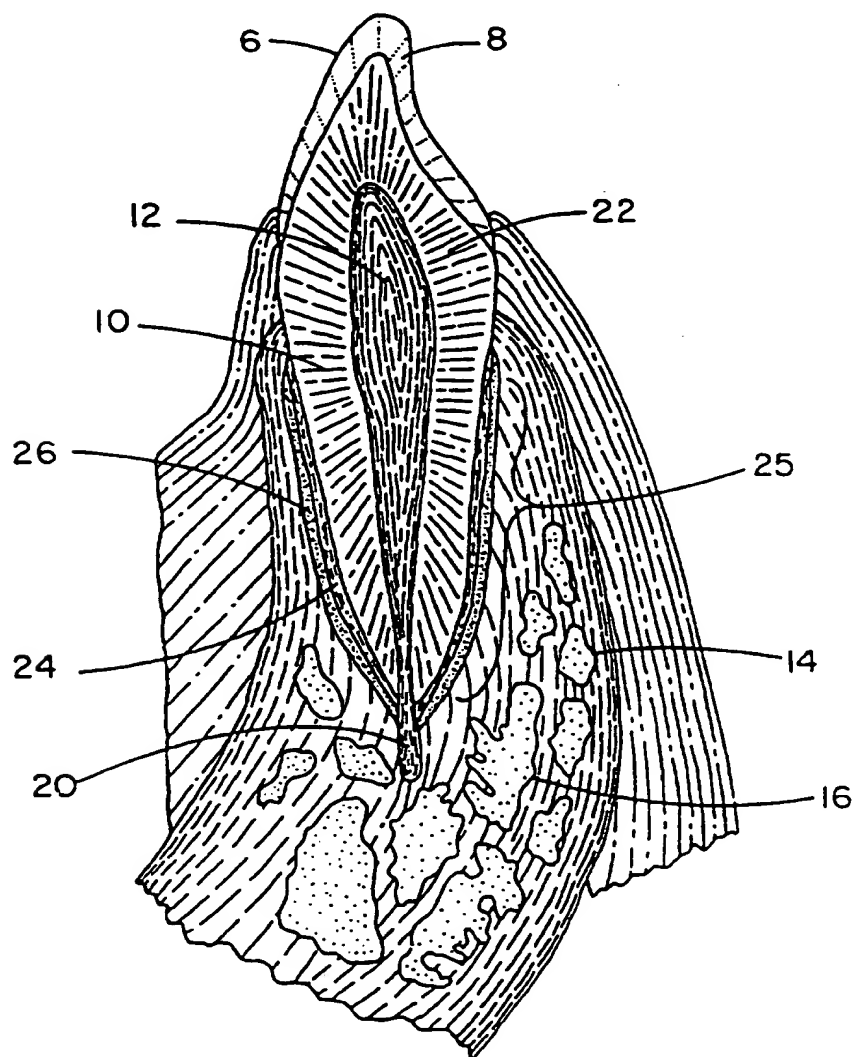
- 1 25. The method of claim 1, 2, 3, 4, 5, 9 or 11 wherein said morphogen comprises a dimeric
2 protein that induces morphogenesis of mammalian dentine tissue, said dimeric protein
3 comprising a pair of folded polypeptides, the amino acid sequence of each of which
4 comprises
- 5 (i) a sequence sharing at least 70% homology with the C-terminal seven cysteine domain
6 of human OP1, residues 38-139 of Seq. ID No. 4;
- 7 (ii) a sequence encoded by a nucleic acid that hybridizes under stringent conditions with
8 nucleic acid encoding said domain of human OP1; or
- 9 (iii) a sequence defined by Generic Sequence 8, Seq. ID No. 2.
- 1 26. The method of claim 25 wherein said sequence of said morphogen polypeptides has
2 greater than about 60% identity with said domain of human OP1.
- 1 27. The method of claim 25 wherein said sequence of said morphogen polypeptides is defined
2 by OPX, Seq. ID No. 3.
- 1 28. The method of claim 25 wherein said sequence of said morphogen polypeptides is selected
2 independently in each said polypeptide from the sequences of the C-terminal seven
3 cysteine domains of human OP1, mouse OP1, human OP2, mouse OP2, mouse OP3,
4 Drosophila 60A protein, Xenopus Vg1, mouse Vgr-1, mouse GDF-1, Drosophila DPP,
5 CBMP2A, CBMP2B, BMP3, BMP5, BMP6 (shown in Seq. ID Nos. 4, 5, 6, 7, 8, 9, 10,
6 11, 12, 13, 24, 26, 27, 28 and 29), and allelic, phylogenetic and biosynthetic variants
7 thereof.
- 1 29. The method of claim 25 wherein said sequence of said morphogen polypeptides is
2 selected, in each said polypeptide, from the sequences of the C-terminal seven cysteine
3 domains of human OP-1, human OP-2, mouse OP-1, mouse OP-2, mouse OP-3 and
4 Drosophila 60A protein (shown in Seq. ID Nos. 4, 5, 6, 7, 24, and 26), and allelic,
5 phylogenetic and biosynthetic variants thereof.
- 1 30. The method of claim 25 wherein said morphogen is solubilized by association with at least
2 one morphogen prodomain polypeptide or solubility-enhancing fragment thereof.

- 82 -

- 3 31. The method of claim 25 wherein said morphogen is obtained from culture medium of
4 morphogen-secreting mammalian cells.
- 1 32. A composition for stimulating morphogenesis of dentine in a mammalian tooth,
2 comprising a morphogen and a cofactor that mitigates symptoms associated with tooth
3 damage.
- 1 33. The composition of claim 32 wherein said cofactor is selected from an antibiotic,
2 antiseptic, anaesthetic, analgesic or nonsteroidal anti-inflammatory agent suitable for
3 dental use.
- 1 34. The composition of claim 32 wherein the concentration of said morphogen therein is
2 effective for stimulating formation of reparative dentin.
- 1 35. The composition of claim 34 wherein said morphogen and said cofactor are dispersed in a
2 physiologically acceptable liquid vehicle.
- 1 36. The composition of claim 34 wherein said liquid vehicle evaporates or is viscous under
2 physiological conditions.
- 1 37. The composition of claim 34 wherein said morphogen and said cofactor are adsorbed on a
2 biocompatible, acellular matrix suitable for sealing or filling defects in mammalian teeth.
- 1 38. The composition of claim 37 wherein said matrix is bioresorbable.
- 1 39. The composition of claim 38 wherein said matrix is derived from mammalian dental tissue.
- 1 40. The composition of claim 38 wherein said matrix comprises collagen, glycosaminoglycans
2 or proteoglycans of the same types as occurring naturally in mammalian dental tissue.
- 1 41. The composition of claim 32 wherein said morphogen comprises a dimeric protein that
2 induces morphogenesis of mammalian dentin tissue, said dimeric protein comprising a pair
3 of folded polypeptides, the amino acid sequence of each of which comprises
4 (i) a sequence sharing at least 70% homology with the C-terminal seven cysteine domain
5 f human OP1, residues 38-139 of Seq. ID No. 4;

- 83 -

- 6 (ii) a sequence encoded by a nucleic acid that hybridizes under stringent conditions with
7 nucleic acid encoding said domain of human OP1; or
8 (iii) a sequence defined by Generic Sequence 8, Seq. ID No. 2.
- 1 42. The composition of claim 41 wherein said sequence of said morphogen polypeptides
2 shares at least 80% homology with said domain of human OP1.
- 1 43. The composition of claim 42 wherein said sequence of said morphogen polypeptides has
2 greater than about 60% identity with said domain of human OP1.
- 1 44. The composition of claim 43 wherein said sequence of said morphogen polypeptides has
2 greater than about 65% identity with said domain of human OP1.
- 1 45. The composition of claim 41 wherein said sequence of said morphogen polypeptides is
2 defined by OPX, Seq. ID No. 3.
- 1 46. The composition of claim 41 wherein said sequence of said morphogen polypeptides is
2 selected independently from the sequences of the C-terminal seven cysteine domains of
3 human OP1, mouse OP1, human OP2, mouse OP2, mouse OP3, Drosophila 60A protein,
4 Xenopus Vg1, mouse Vgr-1, mouse GDF-1, Drosophila DPP, CBMP2A, CBMP2B,
5 BMP3, BMP5, BMP6 (shown in Seq. ID Nos. 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 24, 26, 27,
6 28 and 29), and allelic, phylogenetic and biosynthetic variants thereof.
- 1 47. The composition of claim 41 wherein said sequence of said morphogen polypeptides is
2 selected, in each said polypeptide, from the sequences of the C-terminal seven cysteine
3 domains of human OP-1, human OP-2, mouse OP-1, mouse OP-2, mouse OP-3 and
4 Drosophila 60A protein (shown in Seq. ID Nos. 4, 5, 6, 7, 24, and 26), and allelic,
5 phylogenetic and biosynthetic variants thereof.
- 1 48. The composition of claim 41 wherein said morphogen is solubilized by association with at
2 least one morphogen prodomain polypeptide or a solubility-enhancing fragment thereof.
- 1 49. The composition of claim 41 wherein said morphogen is obtained from culture medium f
2 morphogen-secreting mammalian cells.

*Fig. 1*

2/17

	Cys	Lys	Lys	Lys	His	Glu	Leu	Tyr	Val
hOP-1
mOP-1	...	Arg	...	Arg	...	...	...	...	...
hOP-2	...	Arg	Arg	...	...	...	...	...	...
mOP-2	...	Arg	Arg	...	...	...	...	...	...
mOP-3	...	Arg	Arg	...	...	...	...	...	...
DPP	...	Arg	Arg	...	...	Ser	...	...	...
Vgl	Lys	Arg	His	His	...	...	...
Vgr-1	Gly	...	...	...
CBMP-2A	Arg	...	...	Pro	...	...	...
CBMP-2B	...	Arg	Arg	...	...	Ser	...	...	...
BMP3	...	Ala	Arg	Arg	Arg	Tyr	...	Lys	...
GDF-1	...	Arg	Ala	Arg	Arg	Arg	...	...	...
60A	...	Gln	Met	Glu	Glu	Thr	...	...	...
BMP5
BMP6	...	Arg	...	...	...	...	...	...	...
	1					5			

FIGURE 2-1

4/17

	Trp	Ile	Ile	Ala	Pro	Glu	Gly	Tyr	Ala
hOP-1
mOP-1	...	Val	...	...	...	Gln	...	...	Ser
hOP-2	...	Val	...	...	...	Gln	...	...	Ser
mOP-2	Ser	Val	...	...	...	Gln	...	...	Ser
mOP-3	Val	...	...	Leu	...	...	Asp
DPP	...	Val	...	...	...	Gln	...	...	Met
Vgl	Lys	...	...	...
Vgr-1	Val	...	...	Pro	...	...	His
CBMP-2A	Val	...	...	Pro	...	...	Gln
CBMP-2B	Ser	...	Lys	Ser	Phe	Asp
BMP3	...	Val	...	...	...	Arg	...	Phe	Leu
GDF-1	Gly
60A
BMP5
BMP6	Lys	...	...	...
									25
									20

FIGURE 2-3

5/17

hOP-1	Ala	Tyr	Tyr	Cys	Glu	Gly	Glu	Cys	Ala
mOP-1	...	...	...	...	...	...	...	...	...
hOP-2	...	...	...	...	...	...	...	...	Ser
mOP-2	...	...	...	...	...	...	...	...	...
mOP-3	...	...	...	...	Ala	...	...	...	Ile
DPP	...	...	...	...	His	...	Lys	...	Pro
Vgl	...	Asn	...	...	Tyr	...	...	...	Pro
Vgr-1	...	Asn	...	...	Asp	...	...	...	Ser
CBMP-2A	...	Phe	...	...	His	...	Glu	...	Pro
CBMP-2B	...	Phe	...	...	His	...	Asp	...	Pro
BMP3	...	...	...	...	Ser	...	Ala	...	Gln
GDF-1	...	Asn	...	...	Gln	...	Gln	...	...
60A	...	Phe	...	...	Ser	...	...	...	Asn
BMP5	...	Phe	...	...	Asp	...	...	...	Ser
BMP6	...	Asn	...	...	Asp	...	...	...	Ser
				30					35

FIGURE 2-4

6/17

	hOP-1	Phe	Pro	Leu	Asn	Ser	Tyr	Met	Asn	Ala
mOP-1
hOP-2	Asp	...	Cys	...	...	...
mOP-2	Asp	...	Cys	...	...	...
mOP-3	Cys	...	...	Ser
DPP	Ala	Asp	His	Phe	...	Ser
Vgl	...	Tyr	...	...	Thr	Glu	Ile	Leu	...	Gly
Vgr-1	Ala	His	...	...	...
CBMP-2A	Ala	Asp	His	Leu	...	Ser
CBMP-2B	Ala	Asp	His	Leu	...	Ser
GDF-1	Leu	...	...	Val	Ala	Leu	Ser	Gly	Ser**	...
BMP3	Met	Pro	Lys	Ser	Leu	Lys	Pro
60A	Ala	His	...	...	...
BMP5	Ala	His	Met	...	...
BMP6	Ala	His	Met	...	...

40

FIGURE 2-5

7/17

	Thr	Asn	His	Ala	Ile	Val	Gln	Thr	Leu
hOP-1	...	...	...	...	...	...	...	...	...
mOP-1	...	...	...	...	...	Leu	...	Ser	...
hOP-2	...	...	...	...	...	Leu	...	Ser	...
mOP-2	...	...	...	...	Thr	Met	...	Ala	...
mOP-3	...	...	...	...	Val	...	...	...	...
DPP	...	...	...	...	...	Leu	...	...	...
Vgl	Ser	...	...	...	...	...	...	...	...
Vgr-1	...	...	...	...	...	...	...	...	...
CBMP-2A	...	...	...	...	...	...	...	...	...
CBMP-2B	...	...	...	...	...	...	...	...	...
BMP3	Ser	...	...	...	Thr	Ile	...	Ser	Ile
GDF-1	Leu	...	...	...	Val	Leu	Arg	Ala	...
60A	...	...	...	...	...	...	...	...	...
BMP5	...	...	...	...	...	...	...	...	...
BMP6	...	...	...	...	...	...	...	...	...
	45					50			

FIGURE 2-6

8/17

hOP-1	Val	His	Phe	Ile	Asn	Pro	Glu	Thr	Val
mOP-1	...	...	...	...	...	...	Asp	...	...
hOP-2	...	His	Leu	Met	Lys	...	Asn	Ala	...
mOP-2	...	His	Leu	Met	Lys	...	Asp	Val	...
mOP-3	...	...	Leu	Met	Lys	...	Asp	Ile	Ile
DPP	...	Asn	Asn	Asn	...	...	Gly	Lys	...
Vgl	...	...	Ser	...	Glu	...	...	Asp	Ile
Vgr-1	...	...	Val	Met	...	...	...	Tyr	...
CBMP-2A	...	Asn	Ser	Val	...	Ser	...	Lys	Ile
CBMP-2B	...	Asn	Ser	Val	...	Ser	...	Ser	Ile
BMP3	...	Arg	Ala**	Gly	Val	Val	Pro	Gly	Ile
GDF-1	Met	...	Ala	Ala	Ala	...	Gly	Ala	Ala
60A	...	...	Leu	Leu	Glu	...	Lys	Lys	...
BMP5	...	...	Leu	Met	Phe	...	Asp	His	...
BMP6	...	...	Leu	Met	...	...	...	Tyr	...
		55					60		

FIGURE 2-7

9/17

	Pro	Lys	Pro	Cys	Cys	Ala	Pro	Thr	Gln
hOP-1
mOP-1	Ala	...	...	...	...	...	Lys
hOP-2	Ala	...	...	...	...	...	Lys
mOP-2	Val	...	...	Val	...	...	Glu
mOP-3	Ala	...	...	Val	...	...	...
DPP	Leu	...	...	...	...	...	Lys
Vgl	Lys
Vgr-1	Ala	...	...	Val	...	...	Glu
CBMP-2A	Ala	...	...	Val	...	...	Glu
CBMP-2B	Ala	...	...	Val	...	...	Lys
BMP3	...	Glu	...	...	...	Val	...	Glu	Arg
GDF-1	Asp	Leu	...	...	...	Val	...	Ala	Arg
60A	Arg
BMP5	Lys
BMP6	Lys
									70
									65

FIGURE 2-8

11/17

hOP-1	Asp	Asp	Ser	Ser	Asn	Val	Ile	Leu	Lys
mOP-1	...	...	...	...	...	...	...	...	...
hOP-2	...	Ser	...	Asn	...	...	...	...	Arg
mOP-2	...	Ser	...	Asn	...	...	...	...	Arg
mOP-3	...	Arg	Asn	Asn	...	...	...	...	Arg
DPP	Asn	...	Gln	...	Thr	...	Val	...	...
Vgl	...	Asn	Asn	Asp	...	...	Val	...	Arg
Vgr-1	...	...	Asn	...	...	...	...	...	...
CBMP-2A	...	Glu	Asn	Glu	Lys	...	Val	...	...
CBMP-2B	...	Glu	Tyr	Asp	Lys	...	Val	...	...
BMP3	...	Glu	Asn	Lys	...	...	Val	...	...
GDF-1	...	Asn	...	Asp	...	...	Val	...	Arg
60A	Leu	Asn	Asp	Glu	...	...	Asn	...	...
BMP5	...	...	...	...	...	...	...	...	...
BMP6	...	...	Asn	...	...	...	...	...	...

85

FIGURE 2-10

12/17

	Lys	Tyr	Arg	Asn	Met	Val	Val	Arg
hOP-1	...	...	...	...	...	...	...	...
mOP-1	...	His	...	...	...	...	...	Lys
hOP-2	...	His	...	...	...	...	...	Lys
mOP-3	Arg	Glu	...	...	...	...	...	Gln
DPP	Asn	...	Gln	Glu	...	Thr	...	Val
Vgl	His	...	Glu	...	...	Ala	...	Asp
Vgr-1	...	...	...	...	...	...	...	...
CBMP-2A	Asn	...	Gln	Asp	...	...	...	Glu
CBMP-2B	Asn	...	Gln	Glu	...	...	...	Glu
BMP3	Val	...	Pro	...	...	Thr	...	Glu
GDF-1	Gln	...	Glu	Asp	...	...	...	Asp
60A	...	...	...	...	...	Ile	...	Lys
BMP5	...	...	...	...	...	...	...	...
BMP6	...	...	...	Trp	...	...	...	...
	90					95		

FIGURE 2-11

13/17

	hOP-1	Ala	Cys	Gly	Cys	His
mOP-1	...	...	...	...	...	...
hOP-2	...	...	...	...	...	...
mOP-2	...	...	...	...	...	...
mOP-3	...	...	...	...	...	...
DPP	Gly	...	...	...	...	Arg
Vgl	Glu	...	...	...	...	Arg
Vgr-1	...	...	...	...	...	...
CBMP-2A	Gly	...	...	...	...	Arg
CBMP-2B	Gly	...	...	...	...	Arg
BMP3	Ser	...	...	Ala	...	Arg
GDF-1	Glu	...	...	...	...	Arg
60A	Ser	...	...	...	...	...
BMP5	Ser	...	...	...	...	...
BMP6	...	...	...	...	...	...
				100		

**Between residues 56 and 57 of BMP3 is a Val residue; between residues 43 and 44 of GDF-1 lies the amino acid sequence Gly-Gly-Pro-Pro.

254GMF2054/59.50926-1

FIGURE 2-12

14/17

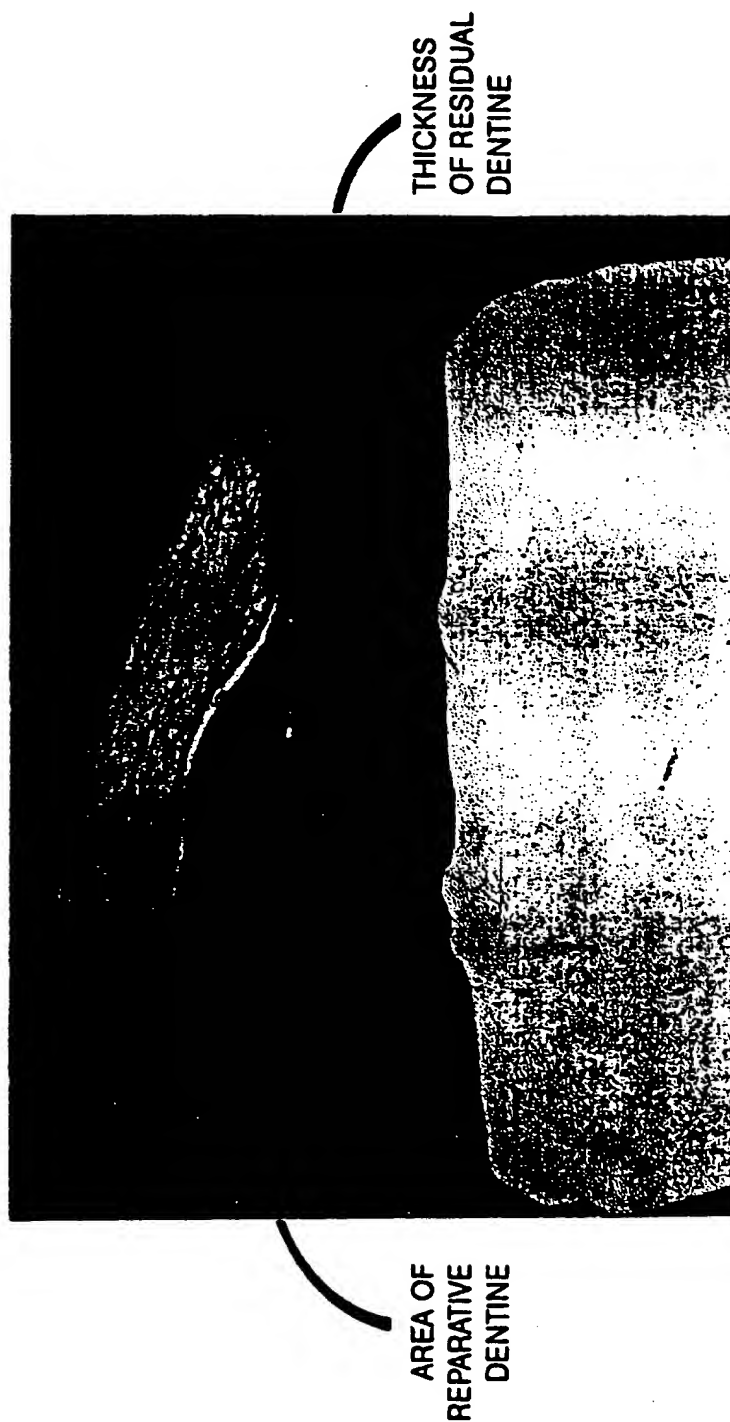


FIG. 3

15/17

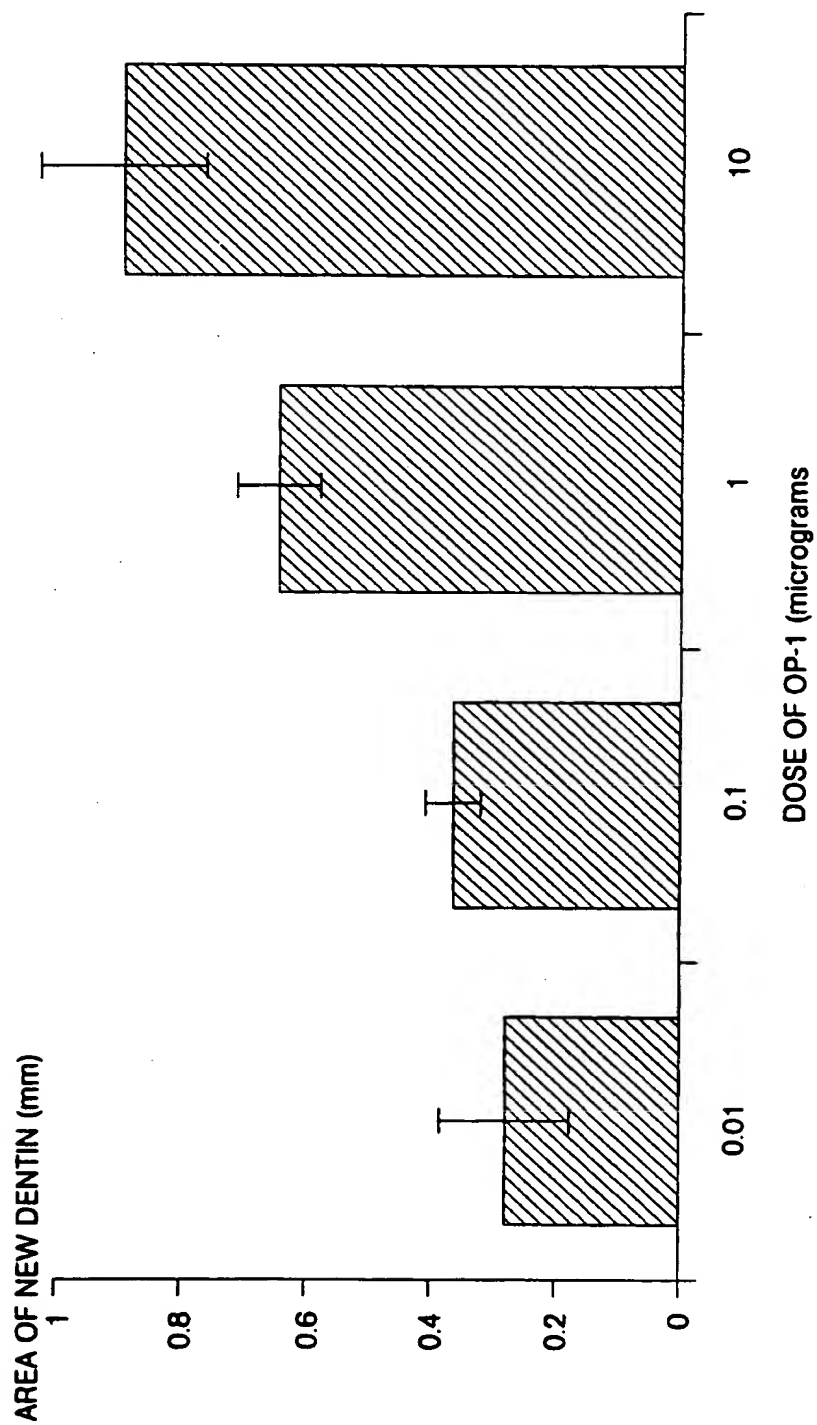


Fig. 4

16/17

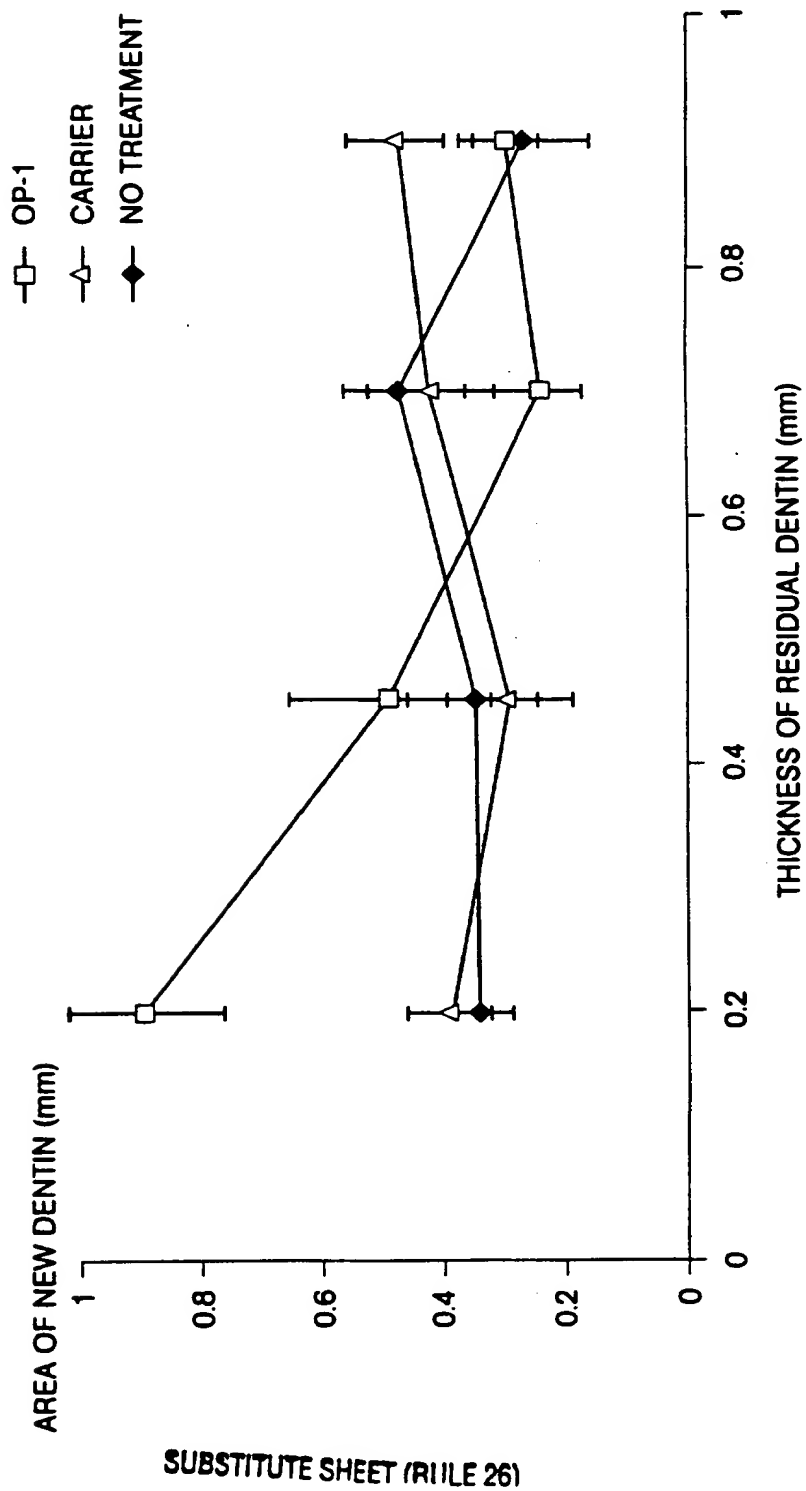


Fig. 5

17/17

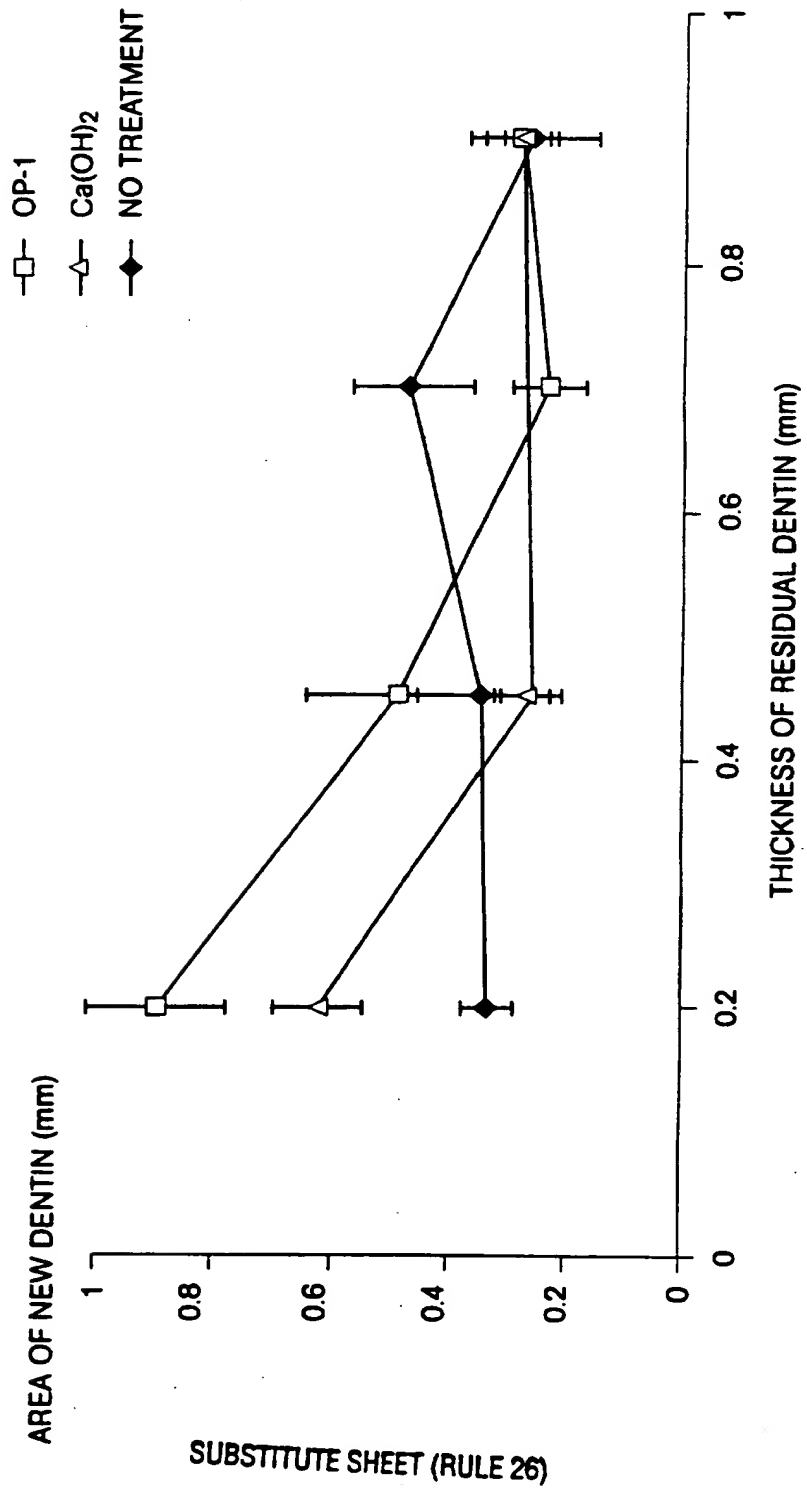


Fig. 6

INTERNATIONAL SEARCH REPORT

Internat. Application No.

PCT/US 96/02169

A. CLASSIFICATION F SUBJECT MATTER
IPC 6 A61K38/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 A61K C07K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO,A,94 06399 (CREATIVE BIOMOLECULES INC) 31 March 1994 see page 4, line 3 - page 32, line 5 see page 36, line 15 - page 50, line 18 see page 51, line 15 - page 54, line 13; examples	1-49
X	WO,A,92 15323 (CREATIVE BIOMOLECULES, INC.) 17 September 1992 see page 6, line 26 - page 7, line 27 see page 11, line 1 - page 26, line 18 see page 64, line 1 - page 65, line 5 --- -/--	1,3,9, 14,19, 20,22, 23, 25-29,31

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"A" document member of the same patent family

Date of the actual completion of the international search

10 July 1996

Date of mailing of the international search report

25. 07. 96

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl,
Fax (+ 31-70) 340-3016

Authorized officer

Montero Lopez, B

INTERNATIONAL SEARCH REPORT

International Application No.

PCT/US 96/02169

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>ARCH. ORAL BIOL., vol. 38, no. 7, 1993, pages 571-576, XP000573091 R. BRUCE RUTHERFORD ET AL.: "Induction of reparative dentine formation in monkeys by recombinant human osteogenic protein-1" cited in the application see the summary see page 571, left-hand column, paragraph 2 - page 572, left-hand column, paragraph 3 see page 572, right-hand column, paragraph 1 see page 572, right-hand column, last paragraph - page 573, left-hand column, paragraph 2 see page 573, right-hand column, paragraph 4 - page 576, left-hand column, paragraph 1</p> <p style="text-align: center;">---</p>	<p>1-4,6,7, 9,14,19, 20,22, 23, 25-29,31</p>
X	<p>ARCHS. ORAL BIOL., vol. 35, no. 7, 1990, pages 493-497, XP000573089 M. NAKASHIMA: "The induction of reparative dentine in the amputated dental pulp of the dog by bone morphogenetic protein" cited in the application see page 493, left-hand column, paragraph 1 - right-hand column, paragraph 1 see page 493, right-hand column, paragraph 3 see page 494, left-hand column, paragraph 4 - paragraph 5 see page 494, right-hand column, paragraph 2 - page 497, left-hand column, paragraph 2</p> <p style="text-align: center;">---</p>	<p>1-4,6,7, 9,14,15, 19,25-29</p>
X	<p>MOL. PATHOG. PERIODONTAL DIS. (1994), 427-37. EDITOR(S): GENCO, ROBERT. PUBLISHER: AM. SOC. MICROBIOL., WASHINGTON, D. C. CODEN: 61LAAZ, 1994, XP000576244 RUTHERFORD, BRUCE ET AL: "Role of osteogenic (bone morphogenetic) protein and platelet-derived growth factor in periodontal wound healing" see page 427, paragraph 3 - page 428, paragraph 1 see page 432, paragraph 4 - page 435, paragraph 1</p> <p style="text-align: center;">---</p> <p style="text-align: center;">-/--</p>	<p>1-3,6,7, 9,14, 25-29</p>

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 96/02169

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	<p>RUTHERFORD B ET AL: "OSTEOGENIC PROTEIN-1 INDUCES FORMATION OF REPARATIVE DENTIN." , JOINT MEETING OF THE INTERNATIONAL ASSOCIATION FOR DENTAL RESEARCH, THE AMERICAN ASSOCIATION OF DENTAL RESEARCH AND THE CANADIAN ASSOCIATION OF DENTAL RESEARCH, CHICAGO, ILLINOIS, USA, MARCH 10-14, 1993. J DENT RES 72 (ABSTR. SPEC. ISSUE). 1993. 213. XP002008041 see abstract</p> <p style="text-align: center;">-----</p>	<p>1-4,7,9, 14,22, 25-29,31</p>

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US96/02169

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
Remark: Although claims 1-31 are directed to a method of treatment of the human/animal body, the search has been carried out and based on the alleged effects of the compound.
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/US 96/02169

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO-A-9406399	31-03-94	AU-B- 4795193	03-03-94
		AU-B- 4797193	03-03-94
		AU-B- 4995593	03-03-94
		AU-B- 5129293	12-04-94
		AU-B- 5129393	12-04-94
		AU-B- 5162393	12-04-94
		AU-B- 5290893	12-04-94
		AU-B- 5590094	24-05-94
		CA-A- 2141554	17-02-94
		CA-A- 2141555	17-02-94
		CA-A- 2141556	17-02-94
		CA-A- 2147598	11-05-94
		EP-A- 0652953	17-05-95
		EP-A- 0653942	24-05-95
		EP-A- 0661933	12-07-95
		EP-A- 0665739	09-08-95
		EP-A- 0661987	12-07-95
		EP-A- 0680334	08-11-95
		EP-A- 0672064	20-09-95
		JP-T- 7509611	26-10-95
		JP-T- 7509720	26-10-95
		JP-T- 7509721	26-10-95
		JP-T- 8501779	27-02-96
		JP-T- 8501558	20-02-96
		JP-T- 8501315	13-02-96
		JP-T- 8503198	09-04-96
		WO-A- 9403600	17-02-94
		WO-A- 9403075	17-02-94
		WO-A- 9403200	17-02-94
		WO-A- 9406447	31-03-94
		WO-A- 9406449	31-03-94
		WO-A- 9406420	31-03-94
		WO-A- 9410203	11-05-94
WO-A-9215323	17-09-92	AU-B- 660019	08-06-95
		AU-B- 1754392	06-10-92
		CA-A- 2104678	12-09-92
		EP-A- 0575555	29-12-93
		JP-T- 6506360	21-07-94